

# Improving the Safety of Ambulatory Intravenous Chemotherapy in Canada

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Improving the Safety of Ambulatory  
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## Main Messages

- Elastomeric ambulatory infusion pumps (AIPs) are a simple way of preventing massive flow rate errors that can occur with electronic programmable pumps. However improved staff and patient education is required to understand and improve flow rate accuracy.
- Models of elastomeric AIPs with different flow rates should be stored separately from each other in pharmacy areas to prevent selection errors.
- Chemotherapy regimens and protocols should be standardized at the provincial level.
- Preprinted orders should be designed according to guidelines to be released at [www.humanfactors.ca](http://www.humanfactors.ca).
- Free-form chemotherapy orders should be avoided.
- Approximate flow rate (in the same units as the pump, e.g., mL/hr) should be included on pharmacy-generated chemotherapy labels and/or preprinted orders for infusions administered via large volume infusion pumps as well as AIPs.
- Only one chemotherapy preparation should be mixed in the biological safety cabinet (BSC) at a time.
- Labels and/or mixing instructions should be paired at all times with their associated preparation supplies and final prepared product.
- A second individual should check that the correct diluent *type* and *volume* have been drawn up in the syringe for reconstitution.

- Research examining the quality mixed chemotherapy bags through techniques such as high-performance liquid chromatography is necessary to establish the mixing error rate in Canadian chemotherapy pharmacies.

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## **Executive Summary**

### ***Context***

Incidents with IV ambulatory chemotherapy, including the death of a patient due to a fluorouracil overdose, have continued to highlight the safety risks of this therapy. This research was funded by the Canadian Patient Safety Institute (CPSI), the Canadian Association of Provincial Cancer Agencies (CAPCA), the Institute for Safe Medication Practices (ISMP) Canada, and five provincial cancer care organizations. The goals of the project were to:

1. Identify the current practices for ordering, preparing, labeling, verifying & administering ambulatory IV chemotherapy in Canada,
2. Identify sources of risk in a wide variety of environments,
3. Recommend strategies to reduce risks.

### ***Methods***

Several methodologies were employed in the identification and prioritization of safety issues in ambulatory IV chemotherapy: a survey, field studies and issue prioritization methods.

### ***Results***

A total of 331 physicians, oncology pharmacists, oncology nurses and administrators involved in cancer care from across Canada completed the survey. There was widespread awareness of the fluorouracil incident and root cause analysis report<sup>1</sup>: 95.5% of respondents were aware of the incident and 71% had reviewed the report. In total, 213 incidents were reported by the 331 respondents.

Seventy-five unique issues were identified through analysis of the survey and field study data. Eleven issues achieved hazard scores of 16 or higher and were therefore selected for further analysis. These fell into three themes as shown below:

<b>1. Elastomeric ambulatory infusion pumps (AIPs) and Access Devices</b>	
1.1	Unexplained elastomeric AIP malfunctions
1.2	Elastomeric AIP selection errors
1.3	Homecare and ambulatory devices
1.4	Access devices used with elastomeric AIPs
<b>2. Orders and Labels</b>	
2.1	Change orders
2.2	Pre-printed orders: reuse of forms, handwriting, usability, flexibility
2.3	Large volume general purpose infusion pump programming errors and labeling
2.4	Free-form orders
<b>3. Pharmacy Practices</b>	
3.1	Lack of standard practice in biological safety cabinet (BSC) organization and processes
3.2	No double-check of reconstitution
3.3	Exposure to hazardous drugs

### ***Recommendations***

- Elastomeric ambulatory infusion pumps (AIPs) are a simple way of preventing massive flow rate errors that can occur with electronic programmable pumps. However improved staff and patient education is required to understand and improve flow rate accuracy.
- Models of elastomeric AIPs with different flow rates should be stored separately from each other in pharmacy areas to prevent selection errors.
- Chemotherapy regimens and protocols should be standardized at the provincial level.
- Preprinted orders should be designed according to guidelines released in spring 2010 at [www.humanfactors.ca](http://www.humanfactors.ca).
- Free-form chemotherapy orders should be avoided.

- Approximate flow rate (in the same units as the pump, e.g., mL/hr) should be included on pharmacy-generated chemotherapy labels and/or preprinted orders for infusions administered via large volume infusion pumps as well as AIPs.
- Only one chemotherapy preparation should be mixed in the biological safety cabinet (BSC) at a time.
- Labels and/or mixing instructions should be paired at all times with their associated preparation supplies and final prepared product.
- A second individual should check that the correct diluent *type* and *volume* have been drawn up in the syringe for reconstitution.
- Research examining the quality of mixed chemotherapy bags through techniques such as high-performance liquid chromatography is necessary to establish the mixing error rate in Canadian chemotherapy pharmacies.

## ***Conclusions***

This study identified a number of potential improvements in practice as well as several unexpected safety hazards in IV ambulatory chemotherapy. The findings from this research will be distributed widely across Canada through the CAPCA network starting in spring 2010. Documents and tools will be available for download from [www.humanfactors.ca](http://www.humanfactors.ca).

## **Study Background**

Incidents with IV ambulatory chemotherapy, including the death of a patient due to a fluorouracil overdose, have highlighted the safety risks of this therapy. A root cause analysis (RCA) of the fluorouracil event by the Institute for Safe Medication Practices (ISMP) Canada identified 16 causal factors and made several associated recommendations.<sup>1</sup> These recommendations were relevant to all centres in Canada who provide outpatient IV chemotherapy. However, there was a concern in the oncology safety community that additional safety hazards existed that had not been implicated in the incident. Further, this event highlighted to the community that practices varied from site-to-site and province-to-province, but that little data was available to this effect. Thus, as a follow-up to the fluorouracil RCA, this research was funded by the Canadian Patient Safety Institute (CPSI), the Canadian Association of Provincial Cancer Agencies (CAPCA), ISMP Canada, and five provincial cancer care organizations (BC Cancer Agency, Alberta Cancer Board, CancerCare Manitoba, Cancer Care Ontario and the New Brunswick Cancer Network). The goals of the project were to:

1. Identify the current practices for ordering, preparing, labeling, verifying & administering ambulatory IV chemotherapy in Canada
2. Identify additional sources of risk in a wide variety of environments
3. Recommend strategies to reduce risks

The research team for this project was comprised of human factors (HF) specialists, oncology nurses, pharmacists and medical oncologists from across Canada, and was steered by the CAPCA Systemic Therapy Safety Committee. To achieve the above goals, a multi-method approach was employed, which included a Canada-wide survey, week-long field study visits in

six cancer centres across Canada, and in-depth analysis of issues with multi-disciplinary teams of clinicians, human factors experts and graphic designers.

This report is divided into two main parts. Part A comprises the methods and results related to identifying and prioritizing the safety issues in ambulatory IV chemotherapy, and Part B includes methods and results related to understanding and addressing these issues.

## **Part A: Identifying and Prioritizing the Issues**

### ***Context***

Several methodologies were employed in the identification and prioritization of safety issues in ambulatory IV chemotherapy: a survey, field studies and issue prioritization methods.

### ***Approach***

#### **Survey**

The goals of the survey were to understand current and future practices around the ordering, labeling, verifying, administering, and documenting of ambulatory IV chemotherapy in Canada. Further, we aimed to determine how cancer centres have responded to ISMP Canada's RCA report on the fluorouracil incident,<sup>1</sup> as well as to collect information on other adverse events that have occurred across the country.

The survey was administered through an online tool called Survey Monkey. The target respondents were health professionals at Canadian hospitals and/or cancer centres who had knowledge about ordering, preparing, labeling, administering and verifying practices related to IV chemotherapy in the ambulatory setting.

The link to the survey was distributed via provincial liaisons from the CAPCA Systemic Therapy Safety Committee, the Canadian Association for Nurses in Oncology (CANO) listserv, the Hospital Pharmacy Directors listserv, and through announcements made at the 2008 National Oncology Pharmacy Symposium of the Canadian Association of Pharmacy in Oncology (CAPHO). The survey was accessible online from October 15th, 2008 to December 12th, 2008 in both official languages (French and English).

### **Field Studies**

The goal of the field studies was to thoroughly examine and understand the current practices for ordering, preparing, labeling, verifying, administering and documenting ambulatory IV chemotherapy in Canada, and to identify factors that may contribute to preventable adverse events.

Week-long field studies were conducted in six cancer centres across Canada during the period of October 2008 to February 2009. These centres were deliberately chosen by the steering committee to represent a range of small and large facilities, community and research hospitals, and rural and urban communities:

- Medicine Hat Cancer Centre (AB)
- BC Cancer Agency Vancouver Island Centre (BC)
- Toronto East General Hospital (ON)
- CancerCare Manitoba -MacCharles site (MB)
- Thompson General Hospital (MB)
- Saint John Regional Hospital (NB)

Medical oncologists, pharmacists, pharmacy technicians, oncology nurses and administrative clerks were observed and interviewed as they carried out their work by two human factors (HF) specialists. Hazards with these processes were documented, and differences in practice, technology and culture were noted. Following each field study, data were archived in the following documents:

1. *Detailed process description*: Description of each of the processes observed in the clinic, pharmacy, and treatment areas in plain language.
2. *Process maps*: Simplified visual representations of processes in clinic, pharmacy and treatment areas with boxes and arrows showing the flow of information.
3. *Data repository*: Spreadsheet detailing each step of the chemotherapy administration process in terms of who performs the task, where the task is completed, how the task is completed and any issues or concerns about the task.

Each of these documents was sent to the site coordinator for review and validation to ensure that the researchers had fully and correctly understood the processes.

### **Identification and Prioritization of Safety Issues**

The above methods were useful for identifying current processes. However, to identify potential safety hazards, two methods were adapted for this purpose: Rasmussen's 1997 Risk Management Framework<sup>2-6</sup> and Healthcare Failure Mode and Effect Analysis (HFMEA).<sup>7 8</sup>

### **Rasmussen Framework for Risk Management in a Dynamic Society**

The ultimate aim of this study was to develop generalizable recommendations to improve the safety of ambulatory IV chemotherapy across Canada. Intrinsic to this goal is that recommendations must include every level of the healthcare system directly involved in the

delivery of ambulatory chemotherapy, as well as the levels that contain key decision makers. Thus, it was important to understand how patient safety hazards link to all levels of the system.

Rasmussen's 1997 Risk Management Framework aims to model the "socio-technical system involved in risk management [that] includes several levels ranging from legislators, over managers and work planners, to system operators."<sup>4</sup> The framework explains how and why large-scale accidents occur in complex systems and how they can be prevented, by first examining the factors that influence the behaviour of the system over time. The strength of the framework lies in its ability to provide a structured approach to identifying the actors in the system and the interaction mechanisms between actors and authority levels. It also includes a tool known as the structural hierarchy. To visually represent the actions and decisions across various levels of the system, structural hierarchies were developed for each site. A sample hierarchy can be found in Appendix A.

### **Healthcare Failure Mode and Effect Analysis**

Given the volume and variety of issues identified by analyzing the field study and survey data, a systematic method was required to prioritize which issues warranted further attention. The HFMEA methodology was therefore adapted to evaluate the relative impact of safety issues in three dimensions: severity, probability and detectability.

The ratings for potential severity and probability were adapted from the HFMEA model developed by the United States Department of Veterans Affairs (VA)<sup>9</sup> to account for consequences specific to the field of oncology such as toxicity, unnecessary exposure to chemotherapy, less effective course of treatment, etc. **Table 1** and **2** show severity and probability ratings.

**Table 1 - Severity Ratings**

Severity Rating	Description	Definition
1	Minor	Treatment could be less effective; unknown potential long-term harm (e.g., unnecessary exposure to chemotherapy)
2	Moderate	Patient could be temporarily harmed (e.g., toxicity, intense side effects)
3	Severe	Patient could be permanently harmed
4	Critical	Patient could die

**Table 2 - Probability Ratings**

Probability Rating	Description	Definition
1	Remote	Unlikely to occur (may happen sometime in 5 to 30 years)
2	Uncommon	Possible to occur (may happen sometime in 2 to 5 years)
3	Occasional	Probably will occur (may happen several times in 1 to 2 years)
4	Frequent	Likely to occur immediately or within a short period (may happen several times in one year)

Detectability ratings are not included in the VA’s HFMEA scoring system as detectability is analyzed using a decision tree. We added detectability ratings from the scoring scale based on the South Dakota Association of Healthcare Organizations (SDAHO),<sup>8</sup> (Table 3).

**Table 3 - Detectability Ratings**

Detectability Rating	Description	Definition
1	Moderate	There is a process for double-checks or detection, but the process relies on vigilance and/or is applied only to a sample.
2	Remote	Error can be detected with manual inspection but there is no process in place so the detection is left to chance.
3	Very remote	Failure can be detected only through inspection, which is not feasible or readily done.
4	No chance of detection	No mechanism for detecting the failure.

Severity, probability, and detectability scores were determined for each issue. The issue’s total hazard score was then calculated by multiplying each of these values.

## ***Results: Survey***

A total of 331 physicians, oncology pharmacists, oncology nurses and administrators involved in cancer care in all provinces and territories except Nunavut and the Northwest Territories (where very little or no cancer treatment is administered) completed the survey.

### **Response to the fluorouracil RCA**

There was widespread awareness of the fluorouracil incident and RCA report: 95.5% of respondents were aware of the incident and 71% had reviewed the report. The most frequently reported changes in response to the incident related to staff training, chemotherapy labels, types of infusion devices, and policies and procedures. Respondents from six provinces reported that their centres or provincial cancer organizations had mandated use of elastomeric infusors, as opposed to electronic ambulatory infusion pumps (AIPs), whenever possible for chemotherapy.

### **Types of infusion pumps and ordering systems**

Respondents reported widespread use of electronic AIPs as well as elastomeric infusors. There was a wide variation in the reported makes and models of electronic AIPs in use, the professional group responsible for programming the pumps, and the location where pumps are programmed. In some centres, multiple professional groups were involved in pump programming. None of the reported electronic AIPs were “smart pumps”, or pumps with drug libraries and dose limits. Over 96% of elastomeric infusors were reported to be manufactured by Baxter.

In terms of chemotherapy ordering, 74.5% of respondents indicated that at least some ordering was done using pre-printed paper orders. Only 47% indicated the use of computerized

physician order entry (CPOE) for some orders, and paper orders with no templates were reported as being used by 34.8% of respondents.

### **Reported adverse events with ambulatory IV chemotherapy**

A major objective of this survey was to identify additional types of adverse events - both incidents and near misses - experienced in Canadian cancer centres, so that hazards not identified in the fluorouracil RCA could be discovered. In total, 213 incidents were reported by the 331 respondents. These were analyzed into themes, and are presented in Appendix B in order of severity, from highest to lowest. Note that the same incident may have been reported by multiple respondents so total numbers may not reflect actual incident rates.

These incidents were taken into consideration during the issue prioritization, as well as in the analysis and recommendations phase.

### ***Results: Field Study***

The six centres differ greatly in size, patient volume, and staff complement since they were chosen to represent a broad cross-section of facilities. Some cancer programs operate as units within hospitals, while others as stand-alone cancer centres. Patient volumes between the centres vary from 240 treatments to over 5,000 treatments per year, with the number of staff on shift at any given time ranging from 7 to 23.

The research team found that the sites differ not only in size, but also in their practices, technology and culture:

- **Role of provincial cancer organizations:** Each of the six field study sites has an associated provincial cancer organization. However, the degree of regulation and funding of drug protocols varies greatly between provinces.

- **Patient scheduling model:** Two scheduling approaches were observed across the sites: the one-day model and the multi-day model. In the one-day model, blood work is conducted and reviewed by a clinician in the morning, and treatment is administered in the afternoon of the same day. In the multi-day model, blood work may be done up to three days in advance.
- **Ordering technology:** Only two sites used CPOE. However, even the two CPOE sites, along with two other field study sites, use pre-printed orders for the majority of their regimens.
- **Elastomeric ambulatory infusion pumps (AIPs):** In the survey, 88.5% of respondents had indicated that they use elastomeric AIPs for take-home IV chemotherapy. Four of the field study sites use elastomeric AIPs whereas the two other sites use electronic AIPs for take-home chemotherapy.
- **Models of teamwork:** In clinics, pharmacies and treatment areas, teams are made up of different combinations of medical oncologists, general practitioners, clinical nurse specialists, pharmacists, pharmacy technicians, volunteers, clerks and registered nurses.
- **Efficiency pressure:** The main commonality between sites was the pressure on staff to work quickly. The impact of this efficiency pressure was most evident in pharmacies, where the mixing of drugs was often a bottleneck to patients receiving treatment, especially in the one-day model of scheduling.

## ***Results: Issue Identification and Classification***

Seventy-five unique issues were identified through the Rasmussen Framework and HFMEA of the survey and field study data. Eleven issues achieved hazard scores of 16 or higher and were therefore selected for further analysis. These fell into three themes and are presented in **Table 4.**

**Table 4 - Safety Hazards in Ambulatory IV Chemotherapy**

	<b>Issue</b>	<b>Severity</b>	<b>Probability</b>	<b>Detectability</b>	<b>Hazard Score</b>
<b>1. Elastomeric AIPs and Access Devices</b>					
1.1	Unexplained elastomeric AIP malfunctions	4	4	4	<b>64</b>
1.2	Elastomeric AIP selection errors	4	3	2	<b>24</b>
1.3	Homecare and ambulatory devices	2	4	2	<b>16</b>
1.4	Access devices used with elastomeric AIPs	1	4	4	<b>16</b>
<b>2. Orders and Labels</b>					
2.1	Change orders	3	4	3	<b>36</b>
2.2	Pre-printed orders: reuse of forms, handwriting, usability, flexibility	4	3	2	<b>24</b>
2.3	Large volume general purpose infusion pump programming errors and labeling	3	3	2	<b>18</b>
2.4	Free-form orders	4	2	2	<b>16</b>
<b>3. Pharmacy Practices</b>					
3.1	Lack of standard practice in biological safety cabinet (BSC) organization and processes	4	3	4	<b>48</b>
3.2	No double-check of reconstitution	4	2	4	<b>32</b>
3.3	Exposure to hazardous drugs	1	4	4	<b>16</b>

## **Part B: Understanding and Addressing the Issues**

### ***Context***

Each of the 11 issues with hazard scores of 16 or higher was examined in detail using a customized approach detailed below.

### ***Approach***

The steering committee guided the analysis of the issues, with some requiring more detailed investigation than others. A variety of methods were employed.

## **Literature searches**

Literature searches were conducted for all issues. Databases and search tools were tailored to the topic.

## **Vendor meetings and collaboration**

For Issues 1.1 and 1.2, meetings were held with vendors to better understand the issues, and to discuss possible solutions. Collaboration with Baxter to refine educational materials is still underway, and is expected to continue as a long-term initiative. Meetings have also been conducted with a manufacturer of an electronic AIP who is entering into the chemotherapy market, to discuss chemotherapy safety resources.

## **Small inter-disciplinary working groups**

For Issues 2.1, 2.2, 3.1 and 3.2, small working groups of oncologists, nurses and pharmacists from the research team and steering committee were assembled to provide expert opinion on specific topics. In the case of 2.1 and 2.2, the working group included graphic designers from the Ontario College of Art and Design (OCAD) who created example preprinted order designs.

## **Expert user evaluations**

For Issues 2.1 and 2.2, a small group of medical oncologists, hematologists, pharmacists, nurses and a clerk from across Canada reviewed example preprinted orders and provided their input into the design.

## ***Results and Recommendations***

### **1. Elastomeric AIPs and Access Devices**

Elastomeric ambulatory infusion pumps (also known as “elastomeric devices,” “baby bottles” and “infusors”) are disposable, nonelectric pumps used for a one-time administration of intravenous chemotherapy. The drug is stored in a balloon-like reservoir made of a combination of elastomers that is protected by an outer container. Since the device is nonelectric, there is no programming involved and rate is not displayed, but rather, determined by visual inspection. Results of the survey showed that Baxter is the dominant manufacturer of these pumps in Canada (96%).

#### **1.1. Unexplained elastomeric AIP malfunctions**

Field study participants often noted that infusions given via elastomeric AIPs ran faster or slower than they expected. This observation was consistent with 26 of the adverse events described by survey respondents in this study. Some of the described events appear quite severe, including an infusion of fluorouracil that ran too quickly causing the patient to suffer severe renal failure, and an event where the device infused only half of the drug in the prescribed infusion time. Investigation into these events did not always provide insights into why they performed outside of expected ranges.

Through review of Baxter’s materials and direct communication with members of the company’s marketing and engineering departments, the team came to understand factors affecting performance. The pumps have a nominal flow rate of +/- 10%, meaning that if all conditions are ideal, the pump may infuse up to 10% faster or slower than the labelled rate.

There are five factors that can further increase or decrease the pump flow rate, and these are additive:

- **Fluid viscosity:** Flow rate is most accurate with 5% dextrose. If 0.9% NaCl is used, flow rate will increase by approximately 10%.
- **Head height:** The elastomeric reservoir should be at the same height as the distal end of the patient access site. For each 2.5cm increase/decrease in head height, flow rate increases/decreases by 0.5%.
- **Temperature:** Optimal temperature is 33°C. Each degree Celsius increase/decrease in temperature increases/decreases flow rate by 2.3% respectively.
- **Underfilling:** Pumps run at optimal rates if they are filled to 80% to 100% of the nominal fill volume. If pumps are *underfilled* they will run *faster*.
- **Diameter of access device:** Access system should be 22 gauge or wider. Smaller diameter devices will cause the pump to run more slowly.

Thus, if saline is used, the pump is worn high, the patient is exposed to high temperatures, the bottle is under filled, and the access device is large, the pump can be expected to flow much faster than the nominal rate.

Although some of the reported events were severe, some involved pumps infusing within +/- 10% of the expected infusion times, which is consistent with normal elastomeric pump performance. These findings highlight the fact that normal infusion pump performance may not be fully understood by staff administering and filling the devices, but also that pumps occasionally perform outside expected ranges. It should be noted that in our search of the literature, no studies of the in vivo performance of these pumps could be found. In other words,

the actual flow rates of elastomeric AIPs worn by ambulatory patients who are carrying on with their daily activities have not been established.

## Recommendations

- Elastomeric AIPs are a simple way of preventing massive flow rate errors that can occur with electronic programmable pumps such as in the fluorouracil incident.<sup>1</sup> However improved staff and patient education is required to ensure that the pumps infuse as close to the nominal rate as possible.
  - Education materials should be user-specific so that pharmacy staff, nurses and patients are aware of the factors relevant to their role in preparing, administering and using the device.
  - Ordering physicians should be made aware of the strengths and weaknesses of the technology, and of the importance of proper preparation and use.
  - Education should also include instructions on how to identify a pump failure, and what to do if one occurs.
  - Collaboration with the vendor to improve educational materials is currently underway.
- Research on pump in vivo performance as patients carry out daily tasks would help establish the actual performance and incident rates of these pumps.

### 1.2. Elastomeric AIP selection errors

The flow rate of an elastomeric AIP is primarily determined by the pressure generated by the elastomeric reservoir and the diameter of the flow restrictor. Different models of pumps often resemble each other in size, shape and colour. As cancer programs use elastomeric devices for

more chemotherapy regimens, multiple models may be required to fulfill different infusion rate requirements. If more than one device type is required, there is a risk that pharmacy staff may select the incorrect device for filling and therefore administer the patient's drug at a faster or slower rate than prescribed. Incidents where the wrong device was selected have occurred in several sites in Canada, sometimes with negative patient outcomes. There were 10 such incidents reported in the survey.

### **Recommendations**

- In education materials for pharmacy staff, emphasis should be placed on processes for identifying correct devices, and the impact of device selection errors.
- Education for nurses should include procedures for ensuring that the correct device has been chosen and filled by pharmacy.
- Models of elastomeric AIPs with different flow rates should be stored separately from each other in pharmacy areas to prevent selection errors.
- The manufacturers of the pumps should work to better differentiate different models of pumps through improved use of colour, shape and labeling.
- When smart pump technology becomes available for the ambulatory chemotherapy setting, this technology should be explored for safety performance.

### **1.3. Homecare and ambulatory devices**

As advances are made in drug and pump technology, more care is being provided in the home. However, home care nurses typically have less training in oncology than nurses working in chemotherapy centres. It was observed that there is a communication gap between homecare providers and the cancer centres, and valuable information about the patient's condition and

treatment is not always shared. Specifically, the team became aware of incidents where homecare nurses supplied incorrect information (for example, taught a patient to disconnect their own pump for showering) or did not respond appropriately to a severe incident.

Although the interface between cancer treatment centres and homecare services is an important topic, our steering committee felt that it was out of scope for the current study, especially given the major variation in homecare models within and between provinces. However, this issue is important and needs further exploration.

## **Recommendations**

- More research is needed on how to ensure the safety of chemotherapy patients in homecare environments.
- Cancer treatment clinics should ensure clear information is provided to patients on how to recognize a pump error (for example, an infusion that completes too early) and what to do when one occurs (for example, who to call).

### **1.4. Access devices used with elastomeric AIPs**

Different access devices can be used in the administration of chemotherapy via AIPs. A peripherally inserted central catheter (PICC) is a device that is inserted via a peripheral vein and threaded through to the superior vena cava. A port-a-cath™ (also known as a “port”) is a device that is surgically inserted beneath the skin and connected to a vein with a catheter, which usually terminates in the superior vena cava, just before the right atrium of the heart. Both of these devices can be used to connect an elastomeric device.

There is currently no national standard or established research evidence for determining the type of access device required to meet patients’ needs; to prevent harm to veins or tissue; and to

manage care appropriately over time. Clinicians therefore must currently rely on their professional judgment or the available resources at their site. This is an issue that therefore needs attention from the oncology community to ensure safe and consistent care.

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## Recommendations

- More research is needed to determine the impact of different access devices on elastomeric AIP performance and to determine a standard of care.

## 2. Orders and Labels

### 2.1. Change orders

Timely and accurate communication of changes to chemotherapy orders is essential to the successful preparation and administration of chemotherapy. If pharmacy and nursing are not notified of a change order in a timely manner, or if a modification to a preprinted order is overlooked, the wrong drug may be prepared, a potentially expensive drug may be wasted, or the wrong treatment may be administered with the potential for adverse outcomes for the patient.

The order forms collected in the field studies were observed to be not easily modifiable once an order has been written. Modifications to orders are common, and are often communicated verbally between clinical staff (oncologists, nurses, and pharmacists). Changes are usually documented by marking up the original order, which is sometimes reused for multiple cycles. Each prescriber has a different method for noting modifications, making it difficult for other staff to understand and keep track of the modifications. Reuse of forms also increases the likelihood of a change order being required. We witnessed and were told of many cases of changes to orders going unnoticed by pharmacists and nurses.

The human factors research team has been collaborating with a small working group of medical oncologists, nurses, pharmacists and graphic designers to develop specific guidelines for the contents and design of preprinted order forms. A final report with detailed recommendations,

design examples, and downloadable templates is currently in the final stages of development and will be available in spring 2010 from [www.humanfactors.ca](http://www.humanfactors.ca).

## **Recommendations**

- A pre-printed order form should be used for one cycle only.
- In sites with computerized prescriber order entry (CPOE), timely alerts should be given to pharmacists and nurses when a change has been made to an order
- All sites should establish a systematic process for notifying pharmacists, nurses and clerks when a prescriber has made a change to an order.

### **2.2. Pre-printed orders: reuse of forms, handwriting, usability, flexibility**

Pre-printed orders are templates for ordering chemotherapy regimens and are the most commonly used ordering tool. However, they are not sufficiently flexible for the fluid nature of chemotherapy treatment. Many forms are designed to be used for multiple cycles, and prescribers mark them up with modifications. Poor handwriting makes some orders illegible and prone to interpretation and transcription errors. The forms observed in the field studies were not intuitive or designed with the needs of all the stakeholders in mind. These issues have been addressed through the redesign process used in the development of the pre-printed order design guideline.

## **Recommendations**

- Preprinted orders should be designed according to the guideline, which will be released in spring 2010 at [www.humanfactors.ca](http://www.humanfactors.ca).
- CPOE has the potential to solve some of the above issues with ordering, if implemented well.

### 2.3. Large volume general purpose infusion pump programming errors and labelling

Patients receive the majority of their treatment in the cancer centre via large volume general purpose infusion pumps. These pumps require nurses to enter an infusion flow rate. However, neither the drug labels nor the physicians' orders showed infusion rates in the unit required to program infusion pumps at any of the field study sites. Consequently, nurses must calculate the infusion rate manually beside the patient's bed or chair. Such manual calculation has been found to be prone to human errors.<sup>10</sup>

#### Recommendations

- Approximate flow rate (in the same units as the pump, e.g., mL/hr) should be included on pharmacy-generated chemotherapy labels and/or pre-printed orders for infusions administered via large volume infusion pumps as well as AIPs.<sup>11</sup>
- If infrastructure is available to fully implement and adequately maintain smart pumps with dose error reduction systems, this technology should be considered as a means of improving safety at the bedside for large volume infusions.<sup>10</sup>

### 2.4. Free-form orders

When there is no pre-printed order for a specific protocol, prescribers must use free-form orders or prescription pads. This lack of ordering structure results in prescribers formatting the order in whatever sequence or layout they choose. Given the complexity of chemotherapy protocols, this approach is prone to error, and may be counter-intuitive for pharmacists or nurses who have to interpret the orders. Changes to the orders can be especially difficult to notice if the prescription is used for multiple cycles. Since these forms are not specific to any protocol or regimen, there are no standards or reminders to limit and guide the prescribers. They may order

medications at a dose outside the reasonable dose range for the drug or omit parts of the order. Also, illegible handwriting becomes an even more pressing issue because unlike most pre-printed orders, the prescriber must handwrite all the information for the order. The possibility of an interpretation error increases especially with look-alike drug names (e.g., carboplatin and cisplatin). This ordering method was reported to be used by 35% of respondents for at least some regimens, so it is still fairly common practice.

### **Recommendations**

- Free-form orders should be avoided.
- Chemotherapy regimens and protocols should be standardized at the provincial level, and associated tools such as pre-printed orders and/or CPOE regimens should be provided to prescribers.

### **3. Pharmacy Practices**

A variety of practices were observed across sites for workspace organization, mixing processes, or double-checks in the biological safety cabinets (BSCs), and some practices were inherently more error-prone than others. This finding is of concern because many mixing errors are often undetectable once the drug leaves the BSC. However, in reviewing Canadian and international policies and standards, we found that many of the observed practices were not in violation of these standards, and that each pharmacy staff member seemed to have confidence that their own organizational technique was safe.

### 3.1. Lack of standard practice in organization and processes in biological safety cabinets

One of the field study sites only permits one preparation to be mixed in the BSC at a time, as is mandated by the provincial cancer organization policy. The other sites do not have any regulation on the maximum number of drugs in the BSC and we often observed multiple drugs for multiple patients in the BSC at once. A risk with this approach is that the wrong drug vial could be selected and injected into the diluent bag, and if the correct vial is then shown to the pharmacist, the error would subsequently go undetected.

Drug labelling procedures also vary between centres. At one centre, the label is half-adhered to the diluent bag and only fully adhered by the technician once the drug has been injected. At another centre, the technician adheres a temporary handwritten label to the bag and the computer-generated label is adhered by the pharmacist outside the clean room once the double-check has been conducted. However, in other sites, labels are often stored in physically distinct locations from their associated preparation supplies such as the diluent bag, introducing an opportunity for a label to be applied to the incorrect bag after mixing has occurred. Once this error is made, it can easily remain undetected.

Mixing errors missed in pharmacy would also likely go undetected by the patient and/or care team because the impact of these errors could be consistent with common toxicity reactions to chemotherapy. If these errors are in fact occurring and going undetected in hospital pharmacies, they would also go undetected in research studies that use methods such as

retrospective chart reviews and self-reports, which are commonly employed when establishing error rates,<sup>12-19</sup> leading us to believe that mixing errors are under-reported in the literature.

## Recommendations

- Research examining the quality of mixed chemotherapy bags through techniques such as high-performance liquid chromatography (HPLC) is necessary to establish the mixing error rate in Canadian chemotherapy pharmacies.
- Consistent with international standards,<sup>20</sup> only one chemotherapy preparation should be mixed in the biological safety cabinet (BSC) at a time.
  - This can be achieved if materials for each preparation are staged ahead of time in a bin: diluent bag, drug vials, syringes and label/mixing instructions.
  - These bins can be stacked on a cart or table next to the BSC but only one bin should enter the BSC at a time.
- Labels and/or mixing instructions should be paired at all times with their associated preparation supplies and final prepared product.
- Standardized mixing instructions should be created, preferably through an automated process when the prescription is handled by pharmacy. Handwritten mixing instructions are prone to error and misinterpretation.
- Consider having separate mixing labels/instructions from patient/bag labels so that only information relevant to each user group is contained in the label.
- As a final safety measure, consider weighing diluent bags prior to and after mixing to confirm the correct volumes have been injected. Spectroscopy technology should also be explored for use in chemotherapy preparation verification.<sup>21</sup>

### 3.2. No double-check of reconstitution

Some chemotherapy must be reconstituted prior to mixing, whereby diluent is added to the drug vial and agitated to form the final solution. At four of the six field study sites, no independent check of drug reconstitution was observed. Thus, if the pharmacy technician were to dilute the solute incorrectly, there would be no mechanism to detect this error once the drug is injected into the diluent bag. Depending on the concentration of the drug mixed, the patient could receive a significant overdose or underdose. Most of the policies and standards reviewed do not require an independent check of diluent type and/or volume. Those sites where a check was required did not specifically include diluent type in the check.

#### Recommendation

- A second individual should check that the correct diluent *type* and *volume* have been drawn up in the syringe for reconstitution.

### 3.3. Exposure to hazardous drugs

At the majority of cancer centres, medication infusion bags are spiked by the nurse next to the patient's bed or chair. Staff can be exposed to hazardous drugs as the bags containing these drugs are typically hung at eye level and staff do not wear protective eyewear. Nursing staff in some centres were also observed to not always follow best practice in handling and disposal of chemotherapy bags. It is possible that they were not aware of the hazards these practices posed to their health, or that there were systemic barriers to safe practice such as time pressure and lack of appropriate safety and disposal tools. Some centres have changed their processes so that infusion bags are spiked and primed in the BSC prior to injecting the chemotherapy.

## Recommendations

- To protect nurses and patients from exposure to hazardous drugs, chemotherapy bags should be primed in the BSC prior to mixing or centres should employ the use of closed system drug transfer devices.<sup>22</sup>
- Centres should provide staff with regular education and tools to help them follow established guidelines on safe handling of hazardous drugs (e.g.,<sup>23</sup>).

## Study Conclusions

The first aim of this study was to identify the current practices for ordering, preparing, labelling, verifying & administering ambulatory IV chemotherapy in Canada. Through the survey and field studies, we found a very high awareness of the fluorouracil incident<sup>1</sup> and its associated report and recommendations, illustrating one of the many benefits of incident disclosure. Many centres have made changes to practice as a result of this report, including a major migration away from electronic AIPs to elastomeric AIPs. The most common tool for ordering chemotherapy was pre-printed paper orders. A very wide variety of practices and cultures were observed in the field studies, but one commonality existed across sites: efficiency pressure.

The second aim of the study was to identify sources of risk in a wide variety of environments. Through analysis of the survey and field study data, 75 unique safety issues were identified. Eleven of these were chosen for future study and fell into three themes: elastomeric AIPs and access devices; orders and labels; and pharmacy practices. Some of these issues were unexpected.

The final aim of the study was to recommend strategies to reduce risks with the identified safety issues. A number of recommendations relating to the three themes are provided in this report. They take a variety of forms, from staff training to collaboration with manufacturers, to improved forms design, to changes in mixing workflow, and standardization and simplification of chemotherapy protocols.

A number of future research topics have arisen from this work. Research on in vivo performance of elastomeric AIPs, homecare and chemotherapy treatment, and especially, the quality and safety of mixed IV chemotherapy bags would serve to better understand and improve the safety issues in IV chemotherapy.

The findings from this research will be distributed widely across Canada through the CAPCA network starting in spring 2010. Dissemination will include the findings presented in this report as well as additional information. Documents and tools will be available for download from [www.humanfactors.ca](http://www.humanfactors.ca).

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Improving the Safety of Ambulatory  
Intravenous Chemotherapy in Canada

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## **Appendix B**

### Number of incidents reported in survey, by category

<b><u>Category</u></b>	<b><u>Example</u><sup>1</sup></b>	<b><u>Count</u></b>
<b>Wrong drug/dose/patient</b>		<b>21</b>
Medication administered to incorrect patient	“placed the wrong pump on the wrong pt”	5
Medication ordering error	“A patient was ordered 5 days worth of VAD to be delivered in one day”	7
Mixing error	“problems with pharmacists incorrectly calculating drug volumes in pumps”	9
<b>Medication infused too quickly or too slowly</b>		<b>67</b>
Electronic AIP <sup>2</sup> programming error	“Misprogrammed pump, resulting in Herceptin being infused too quickly.”	21
Elastomeric pump <sup>3</sup> malfunction	“at least two incidents where... infusors have emptied much faster/sooner than they were supposed to and patients were very ill as a result”	26
Wrong elastomeric pump filled and administered	“Incorrect elastometric infuser selected. The result was that the patient received a 7 day infusion in 2 days.”	10
Infusion pump incident- pump type not specified	“5-FU being delivered over a short period of time instead of over 46 hours patient developed severe mucositis but survived.”	10
<b>Medication not infused</b>		<b>47</b>
Line kink with elastomeric pump	“tubing may kink on an elastomeric infuser which prevents the drug from infusing over the prescribed time.”	10
Electronic AIP not started	“at least one incident of a nurse forgetting to start a CADD pump.”	6
Tubing not unclamped	“Numerous cases of pump was not unclamped and patient returned without any drug infusing.”	31
<b>Lines and leaks</b>		<b>47</b>
Issue with connection/line	“one patient's port-a-cath dislodged at night and pt did not call nurse on call”	8
Leak	“leak directly from the baby bottle when the nurse went to hook the patient up, the nurse was exposed to 5FU”	39
<b>Other</b>		<b>31</b>
Other electronic AIP issue	“low battery beeping, battery replaced.”	3
Mechanical failure of electronic AIP	“pump failing to run and an error message given”	6
Patient mishap	“patient cut the tubing line while gardening with her gardening scissors”	14
Extravasation	“Patient's have returned with extravasation from 5FU baby bottles”	8
<b><u>Total</u></b>		<b><u>213</u></b>

<sup>1</sup> Note that examples are exact quotes from respondents: errors in spelling were not corrected.

<sup>2</sup> Ambulatory infusion pump.

<sup>3</sup> Elastomeric pumps, sometimes referred to as “baby bottle” pumps or “infusors”, are disposable, fixed-rate, non-electric pumps used for a one-time administration of intravenous medications.