Assessing the Effectiveness of Five Process Elicitation Methods: A Case Study of Chemotherapy Treatment Plan Review

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Abstract

To reduce the probability of failures and to improve outcomes of safety-critical human-intensive processes, such as health care processes, it is important to be able to rigorously analyze such processes. The quality of that analysis often depends on having an accurate, detailed, and sufficiently complete understanding of the process being analyzed, where this understanding is typically represented as a formal process model that could then drive various rigorous analysis approaches. Developing this understanding and the corresponding formal process model may be difficult and, thus, a variety of process elicitation methods are often used. The work presented in this paper evaluates the effectiveness of five common elicitation methods in terms of their ability to elicit detailed process information necessary to support rigorous process analysis. These methods are employed to elicit typical steps and steps for responding to exceptional situations in a safety-critical health care process, the chemotherapy treatment plan review process. The results indicate strengths and weaknesses of each of the elicitation methods and suggest that it is preferable to apply multiple elicitation methods.

Keywords: Elicitation methods; workflow understanding; human-intensive process; exception handling; safety

1. Introduction

Human-intensive processes (HIPs) play a critical role in society. We say that a process is *human-intensive* if the contributions of human process performers

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have a significant impact on the process outcomes and require substantial domain expertise and insight. Important HIPs, such as many health care processes, often involve complex coordination and interaction among human experts and complex software and/or hardware systems. Such HIPs are also often safety-critical in that defects in their design or errors during their execution can lead to loss of life or to other negative consequences. To reduce the probability of such problems and to improve process outcomes, it is important to analyze HIPs for the presence of a wide range of problems or vulnerabilities, to carefully evaluate the impact of process modifications, and even to provide real-time guidance to process performers [1, 2].

A number of types of rigorous analysis, such as fault-tree analysis [3], failure mode and effects analysis [4], model checking [5], and discrete-event simulation [6], have been applied to HIPs and shown to be useful for process improvement [1, 7, 8, 9, 10]. But the quality of such analyses often depends on having an accurate, detailed, and sufficiently complete understanding of the safety-critical HIPs that are being analyzed. This understanding is typically represented as a formal process model that could then be used as input to various rigorous analysis approaches. The level of detail and the precision of process information that needs to be captured in such a model are typically higher than the level of detail and the precision of process information that are needed for informal and less rigorous analysis approaches. For example, model checking and automated fault-tree analysis might require knowledge of which steps could be performed in a process, the possible orders in which these steps can be performed (including concurrently), the problems, or exceptional situations, that might arise in a process, and how these problems are handled.

Eliciting such detailed and precise process information is difficult. In HIPs, the complex coordination of human and automated agents often results in process knowledge being distributed among several stakeholders. These stakeholders may have different and sometimes conflicting views of the process and may use different terminologies to describe it. Another difficulty stems from the fact that *exceptional*, or abnormal, situations often arise during the *execution*, or performance, of a process [13]. Moreover, errors that can compromise the safety of HIPs may be especially likely to occur on process executions during which exceptions arise [14, 15]. This implies that such executions need to be considered in addition to the typical, or normal, process executions. A further indication that such executions require special scrutiny is the fact that responses to exceptional situations are sometimes referred to as workarounds [13, 16], an indication that these responses may be poorly specified. Spear and Schmidhofer [15] observe that organizations that fail to clearly specify how process performers should respond in different situations suffer from more errors than organizations that specify these aspects of their processes. Thus, it is especially important to elicit and understand the exceptional situations that may arise during executions of a HIP and how process performers should respond to them.

To tackle the difficulties associated with eliciting detailed and precise process information, a variety of process elicitation methods are often used. While the strengths and weaknesses of process elicitation methods have been studied (e.g.,

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[11, 12]), more information is needed about the ability of these methods to elicit the kinds of detailed and precise process information necessary to support rigorous analysis. A recent comprehensive survey of the literature [17] suggests that despite the use of a wide variety of process elicitation methods, little is known about the relative strengths and weaknesses of these methods in terms of their ability to elicit different kinds of process information, particularly information about exceptional situations. There has been work on understanding and specifying the handling of exceptional situations (e.g., [16, 18]), but the focus of this work was on the mechanisms for handling exceptions and how to precisely describe these mechanisms, not on the methods used to elicit the handling of exceptional situations in processes.

The work presented here is a step toward understanding the strengths and weaknesses of some of the most frequently used process elicitation methods in terms of their ability to elicit detailed process information needed for rigorous process analyses, and in particular information about exceptional situations in HIPs. As part of a larger project [1, 25] investigating the use of automated analysis techniques to improve the safety and efficiency of medical processes, we conducted a case study evaluating common elicitation methods applied to one safety-critical health care process, chemotherapy treatment plan review. We selected five elicitation methods: direct observations; unstructured interviews; and three semi-structured interview methods based on partial scenario descriptions, complete scenario descriptions, and full process descriptions, respectively. These are some of the most commonly used elicitation methods (e.g., [19, 17, 20, 21, 22, 23, 24]) and were all readily applicable to our selected case study. Specifically, we chose observations and interviews, because a recent comprehensive study of the workflow/process literature found that observations and interviews were the most frequently used methods [17]. We chose the semi-structured interview methods, because we were interested in eliciting process steps and the supporting materials are suitable for eliciting this kind of process information.

Our work specifically focuses on how well these methods elicit two kinds of process steps: 1) typical steps in the process (i.e., normal process steps), which include steps for recognizing exceptional situations and other process steps necessary to carry out the process when no exceptional situations arise, and 2) steps for responding to exceptional situations. We also evaluated the selected elicitation methods in terms of their abilities to discover disagreements among process performers about how the process is to be executed. The results indicate strengths and weaknesses of each elicitation method and show that each method contributed to the understanding of the process, suggesting that it is preferable to apply multiple elicitation methods when trying to develop a robust understanding of a complex process.

The rest of this paper is organized as follows. Section 2 presents the research method for evaluating the five process elicitation methods, Section 3 presents the evaluation results, and Section 4 discusses these results including threats to their validity. Section 5 summarizes the contributions of this work and describes future work.

2. Methods

To evaluate the selected five elicitation methods, we used them to elicit information about a chemotherapy treatment plan review process. We chose this safety-critical HIP because it had considerable complexity, especially with respect to exceptional situations. This process elicitation was part of a larger project on medical safety focusing on creating detailed formal process models and on evaluating formal analysis approaches, such as model checking and fault-tree analysis, in terms of their ability to support improvement of medical processes [1, 25]. During this project, a nearly 70% reduction in errors reaching the patient was observed [25].

We applied the selected elicitation methods in a specific order to minimize the influence that an elicitation method might have on process performers during the application of subsequent elicitation methods. We first conducted unstructured interviews to gain an initial understanding of the process and to avoid introducing any of our preconceived notions about the process. We used this initial understanding to construct a formal process model that we then used to support the semi-structured interviews. The process performers involved in the observations were not involved in the unstructured interviews, so they were not influenced by those discussions. We undertook the observations before conducting the semi-structured interviews, which involved questioning the process performers, to avoid having the semi-structured interviews influence the observed behavior. The semi-structured interview methods were applied in an order such that each semi-structured interview method provided more process information to the interviewees than the semi-structured interview method applied before it. The selected order of method application and its potential influence on the results are further discussed in section 4.4.

Our primary goal was to evaluate the selected elicitation methods in terms of their ability to elicit normal process steps and steps for responding to exceptional situations and, thus, effectiveness was determined in terms of the number of elicited steps and whether critical process steps were missed by a method. Method efficiency, a secondary focus in our study, was determined in terms of the time spent with domain experts for each elicitation method and the number of process steps elicited per unit of time. Other evaluation dimensions, such as susceptibility to researchers' bias, the ability of a method to gain information about the context of process performance, and the effect of a method on the psychological state of process performers, are outside the scope of this work and have been extensively studied and reported elsewhere (e.g., [11, 12]).

The rest of this section describes the elicited process, followed by a description of the selected elicitation methods in the order they were applied to this process.

2.1. Elicited Process

We elicited a chemotherapy treatment plan review process, a critical part of outpatient breast cancer chemotherapy administration. Although this process follows recommended care standards, the actual process details were based on

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the procedures recommended at the D'Amour Center for Cancer Care in Western Massachusetts, a comprehensive regional cancer center with a team of over one hundred care providers. This center is part of the Baystate Health system, which serves a population of over 750,000 people.

The chemotherapy treatment plan review process at the D'Amour Center is performed primarily by a Registered Nurse (RN). Hereafter, we use "RN" to refer to the nurses involved in the treatment plan review, but identify nurses involved in the administration of the chemotherapy as "clinic RNs"[1].

Chemotherapy treatment plans differ by cancer type, stage or extent of the disease, goal of therapy, and a patient's tolerance for therapy with specific agents. Therapeutic options may change rapidly as new research findings are released, thus requiring ongoing diligence and review to ensure that the chemotherapy treatment plan is appropriate for the patient and is safely executed by the team of care providers [26, 27]. During the treatment plan review process, RNs perform essential coordinating functions with physicians (to ensure the treatment plan is accurate), schedulers (to ensure chemotherapy appointments on the treatment plan are scheduled correctly), and clinic RNs (to ensure chemotherapy medications are administered as directed in the treatment plan). The RNs also use several data sources when reviewing treatment plans (e.g. clinical notes, electronic medical records (EMRs), paper charts, caresets[2], reference books, and online resources).

2.2. Elicitation Methods

Unstructured Interviews. We conducted six, hour-long, unstructured interviews over the course of six months with a senior RN experienced in reviewing chemotherapy treatment plans. During this period, we were also interviewing other clinicians involved in other parts of the chemotherapy process as our primary goals were to obtain an initial understanding of the overall chemotherapy preparation and administration process and to create a preliminary process model for that overall process. To obtain this preliminary understanding in a reasonable amount of time, it was decided to interview a single clinician from each role (e.g., one RN, one MD, one pharmacist, and one medical assistant). We stopped interviewing the RN after six interviews, because we reached data saturation and the RN expressed satisfaction with the natural language description of the process that we were incrementally producing. The RN was interviewed by a researcher who kept notes and recorded each interview. After each interview, this researcher carefully examined the recording to verify the accuracy of the notes and to capture additional process information not captured in the notes.

In parallel with the unstructured interviews, we created a detailed model of the treatment plan review process in a process modeling notation[3]. We

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[1]At the time we elicited the process, a nurse could be either involved with treatment plan review or with administration of chemotherapy, but not both.

[2]A *careset* is a standardized treatment for a given diagnosis based on best practices.

[3]We used the Little-JIL process modeling notation [28], in large part because it has explicit support for specifying exceptional situations.

did not discuss that model with the RN, because that RN was not familiar with the modeling notation, but we found that the notation's semantic features influenced the questions we asked. For example, in addition to asking about exceptional situations and how process performers should respond to them, we tended to ask what was expected to be true before or after a step was started or finished because the modeling notation supported representing such pre- and post-conditions.

Direct Observations. After completing the unstructured interviews with the senior RN, we observed three other experienced RNs conduct two treatment plan reviews each[4]. We stopped collecting data after six observations because we started to observe largely the same process information—a sign of data saturation.

Because cognitive tasks are often difficult or impossible to observe, the RNs used a think-aloud protocol [29] to verbally describe their cognitive tasks (such as verifying that information on two artifacts matched) while performing the process. For the observations and the subsequent semi-structured interviews, two researchers were present for each observation/interview session and, using the audio recordings from the sessions, reconciled any differences in observation/interview notes after all observations and interviews were complete. Figure 1 shows a sample sequence of observed steps. We hereafter refer to such a sequence of process steps as a *scenario description.*

Semi-structured interviews. We conducted three kinds of semi-structured interviews with each of the three observed RNs and used partial scenario descriptions, complete scenario descriptions, and a full process description respectively, as supporting materials for these interviews. We developed the semi-structured interview materials solely from the unstructured interview findings, and these materials were not updated based on the data from the observations or subsequent interviews. We did so to maintain a consistent process model and thus a consistent basis for comparing all the subsequent elicitation methods. In the semi-structured interviews, we asked each RN the same questions in the same order, but asked clarifying questions as needed.

Semi-structured interviews based on partial scenario descriptions. We presented partial scenario descriptions to the RNs and asked them how they would continue the treatment plan review process given the partial scenario description. We used fifteen plausible scenarios based on the process model created during the unstructured interviews; three prompted the RNs with only normal process steps, while twelve asked the RNs what steps they would perform in response to exceptional situations. Seven sample partial scenario descriptions are shown in Figure 2. Except for the first, each of these asks what steps need to be performed in response to exceptional situations.

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[4]At the time, these were the only RNs available, since the RN who had participated in the unstructured interviews had transferred to a different position.

1. Look up the patient's record in the electronic medical record (EMR)
2. Check if there are several height and weight records in the EMR and whether they are consistent with each other
3. Note that there are not enough entries for patient's height and weight to judge stability of height and weight
4. Retrieve patient chart from the Medical Records department
5. Check if there are several height and weight records in the patient chart and whether they are consistent with each other
6. Note that there are not enough entries for patient's height and weight in the patient chart to judge stability of height and weight
7. Confirm medication name, dose base and cycle info on treatment plan match doctor's clinical note
8. Tell clinic medical assistant (MA) to measure height and weight on next patient visit
9. Hold treatment plan

Figure 1: Sample sequence of observed steps.

1. A triage MA[5] leaves a treatment plan and orders for a patient in your tray. You confirm that pretesting has been done. What do you do next?
2. When you go to check that a patient's height and weight have been entered in the CIS *(the Cancer Center's EMR system)*, you notice they are missing. How do you proceed?
3. When you go to check that a patient's height and weight have been entered in the CIS, you notice the patient's height and weight measurements are stale. How do you proceed?
4. You receive new height and weight measurements for a patient. There is a 6% change in the dose based on these new values. How do you proceed?
5. While reviewing a patient's treatment plan, you notice that the treatment plan was not created from a careset. How do you proceed?
6. While reviewing a patient's treatment plan and orders, you notice the orders were entered by a Fellow. How do you proceed?
7. While verifying doses for a patient, you notice that the height and weight in the treatment plan doesn't match the height and weight in the CIS or in the patient's chart. How do you proceed?

Figure 2: Sample partial scenario descriptions.

Semi-structured interviews based on complete scenario descriptions. We presented each of the RNs with three complete treatment plan review scenario descriptions in free-text form, based on the process model created during the unstructured interviews. The first scenario description represented a normal process execution (i.e., no exceptional situations arise); the second and third included exceptional situations and the responses to those situations. The third scenario description is shown in Figure 3. We asked each RN whether each described scenario was feasible and, if not, what steps should be added, removed, or reordered.

The term "confirm," when used in a step name, means that a check that can potentially fail is performed. For example, "confirm that labs have been done" means that a medical professional checks whether a patient's lab tests have been performed. If that check fails, an exceptional situation is recognized (in this example, the exceptional situation would be that patient's lab tests have not been performed). In scenario descriptions, when "confirm" is used, it is assumed that the check is successful, unless explicitly indicated otherwise. For example, in the scenario description in Figure 3, all checks are successful, except for "confirm existence of chemo orders . . . ," where it is explicitly indicated that the nurse determines that the orders are missing.

Semi-structured interviews based on a full process description. We showed each RN a natural language description of the full process model created during the unstructured interviews. This full process description included the normal process steps, all exceptional situations and all possible responses to exceptional situations elicited during the unstructured interviews. We asked each RN whether the full process description accurately captured the process and, if not, what steps should be added, removed, or reordered.

All materials used in the semi-structured interviews are provided in the appendices.

3. Results

Tables 1 and 2 show all 66 steps elicited during the study. Table 1 shows the 35 normal process steps and Table 2 shows the 31 steps for responding to exceptional situations. 24 of the normal process steps (shown in bold in Table 1) are steps for recognizing exceptional situations. These are precisely the steps whose names start with "confirm." The high percentage (about 69%) of steps for recognizing exceptional situations is consistent with the nature of the treatment plan review process since one of the main goals of that process is to double-check the work of the physician who ordered the chemotherapy treatment and to identify potential problems. The 11 non-bold steps in Table 1 are the steps

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[5]In the D'Amour Center, a Triage MA is a special kind of medical assistant who is responsible for scheduling patient visits.

1. You pick up the treatment plan and the orders that the Triage Medical Assistant (Triage MA) has left.
2. You confirm that labs have been done.
3. You discover that a lab result is missing and the drugs are not platinum based.
4. You tell a Medical Assistant (MA) to draw the labs next time the patient comes.
5. You find out that the patient does not have a scheduled appointment and you tell the Triage MA to schedule one.
6. You put a sticky note on the treatment plan to check for the labs before signing the plan.
7. You confirm that the scans have been done.
8. You confirm the existence of patient height/weight data in the CIS.
9. You confirm that the patient's height/weight are not stale (i.e more than 2 weeks old).
10. You confirm that the treatment plan is created from a careset.
11. You confirm the existence of chemo orders for the patient but you find out that they are missing.
12. You call the oncologist to enter the orders in the system.
13. You put a sticky note on the treatment plan to check for the orders.
14. You stop your work on the treatment plan for this patient and wait until the oncologist enters the orders.
15. (in 2 days) You find out that the oncologist has entered the orders for that patient.
16. You confirm that the orders have been entered by an Attending.
17. You verify the doses:
    (a) You confirm that the height/weight on treatment plan, in CIS, and in the patient chart all match.
    (b) You calculate the patient's body surface area (BSA) using height/weight from CIS.
    (c) You calculate doses using the BSA just calculated and the information from the treatment plan.
    (d) You confirm that the calculated doses match the ones on the chemo orders.
    (e) You confirm that the dose base on treatment plan is consistent with the doses on orders.
18. You check all sticky notes to make sure that everything is completed and you confirm that the labs have been done.
19. You sign the treatment plan.
20. You leave the treatment plan in Triage MA's tray.

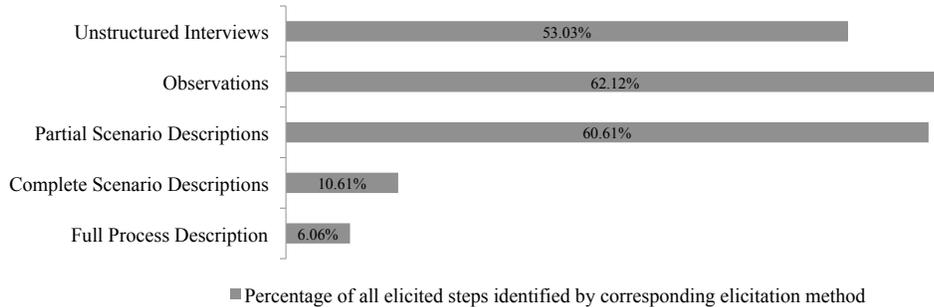Figure 3: Sample complete scenario description.

<table>
<tr><td>Unstructured Interviews</td><td>53.03%</td></tr>
<tr><td>Observations</td><td>62.12%</td></tr>
<tr><td>Partial Scenario Descriptions</td><td>60.61%</td></tr>
<tr><td>Complete Scenario Descriptions</td><td>10.61%</td></tr>
<tr><td>Full Process Description</td><td>6.06%</td></tr>
</table>

■Percentage of all elicited steps identified by corresponding elicitation method

Figure 4: Percentage of steps identified by each elicitation method.

we refer to as "other normal process steps." These steps are necessary to carry out the process when no exceptional situations arise.

The last five columns of Tables 1 and 2 are labeled with the five elicitation methods. Each cell in these columns is color coded to indicate whether the step associated with that specific row was identified, confirmed, disputed, or not addressed by the method associated with that specific column. A step is considered *identified* if it was mentioned by an RN during the unstructured interviews, occurred during the observations, or if during one of the semi-structured interviews an RN mentioned that step and that step was either not included in the materials used in that semi-structured interview elicitation method or the RN mentioned the step before seeing these materials.

A step is considered *confirmed* if an RN agreed the step occurs in the process when that step was presented to the RN as part of the complete scenario descriptions or the full process description. A step is considered *disputed* if at least one interviewee said the step is performed during the treatment plan review process and at least one (potentially the same) interviewee said the step is *not* performed at any time during the process. Disputed steps are discussed in more detail in the next section. A step is considered *not addressed* via the corresponding elicitation method, if that step was not observed, or was not mentioned during the interviews.

4. Discussion

4.1. Contributions of each elicitation method

Based on our findings, it appears to be important to use multiple elicitation methods when understanding how individuals perform a complex process. Each elicitation method failed to identify or confirm critical process steps and no elicitation method alone (see Figure 4) was able to identify more than about 62% of all elicited process steps.

Each elicitation method failed to identify critical process steps. For example, the unstructured interviews and all three kinds of semi-structured interviews

	Step Name	UI	O	PSD	CSD	FPD
1	Pick up treatment plan and orders	■			▦	▦
2	Look up the patient's record in the EMR (e.g., using account number)		■	■		
3	Confirm MD on treatment plan matches MD on clinical note		■	■		
4	**Confirm diagnosis on treatment plan matches diagnosis on MD's clinical note**		■		■	
5	**Confirm medication name, dose base and/or cycle info on treatment plan match MD's clinical note**		■	■	■	
6	**Confirm correct pre-medications for diagnosis (via experience)**				■	■
7	**Confirm correct medications for diagnosis (via experience)**			■		
8	Locate careset corresponding to treatment plan		■			
9	**Confirm correct pre-medications for diagnosis (via careset)**	■	■	■	▦	▦
10	**Confirm correct medications for diagnosis (via careset)**	■	■	■	▦	▦
11	**Confirm patient's height/weight readings are not out-of-date**	■			▦	▦
12	**Confirm presence of several height/weight records (in the EMR) and that they are consistent with one another**	■			▦	▦
13	**Confirm height/weight on treatment plan, EMR, and/or patient chart all match**	■			▦	▦
14	Calculate body surface area (BSA) manually using height/weight from treatment plan or EMR	■			▦	▦
15	Use BSA calculated by computer		■			
16	Calculate dose(s) using dose base(s) on treatment plan or on careset and patient's BSA	■			▦	▦
17	**Confirm existence of chemo orders (for medications and pre-medications) in the EMR**	■			▦	▦
18	**Confirm manually calculated dose matches dose on orders in the EMR**	■	■	■	▦	▦
19	Enter manually calculated BSA in appropriate box in treatment plan		■			
20	**Confirm orders are created by, or approved by, an attending MD (via an MD-to-RN order in EMR system)**			■	▦	▦
21	**Confirm cycle info on treatment plan matches cycle info in careset and/or in orders in EMR**		■			
22	**Confirm the patient is not having concurrent radiation to that specified on the treatment plan (in the EMR)**		■			
23	**Confirm that adequate time has passed since previous chemotherapy treatment plan was completed**		■			
24	**Confirm labs have been done**	■	■		X	X
25	**Confirm scans have been done**	■			▦	
26	**Confirm exams have been done (if any are needed)**	■				
27	**Confirm specified dose base on treatment plan matches dose base in careset**	■	■	■		▦
28	Check sticky notes	■			X	X
29	Sign treatment plan	■	■	■	▦	▦
30	Give treatment plan to scheduler	■	■		▦	▦
31	**Confirm pretesting results are within normal limits**			■		
32	**Confirm there are medication orders for every cycle of the treatment**			■		
33	**Confirm dose base on treatment plan is consistent with doses on orders**	■			▦	▦
34	**Confirm scans have been scheduled**					■
35	**Confirm patient has a scheduled appointment**		■			
	Total number of steps identified by a method	*18 (51%)*	*25 (71%)*	*19 (54%)*	*4 (11%)*	*3 (9%)*

Table 1: The contributions of each method for eliciting normal process steps.
Abbreviations: UI = unstructured interviews; O = observations; PSD = partial scenario descriptions; CSD = complete scenario descriptions; FPD = full process description.
Color coding: black cell = identified step; gray cell = confirmed step; cell with X = disputed step; white cell = not addressed step

	Step Name	UI	O	PSD	CSD	FPD
1	Tell Medical Assistant (MA) or Clinic RN to measure height/weight on next patient visit	■	■	■	▨	▨
2	Call another facility (Breast Center) to inquire about patient's height/weight		■	■		
3	Retrieve patient chart from medical records		■	■		
4	Enter height/weight from patient chart into the EMR	■				X
5	Ask the person who entered the height/weight in the patient's chart to enter the height/weight into the EMR			■		
6	Write a nursing order to measure height/weight on day of treatment			■	■	■
7	Write missing diagnosis information on the paper copy of treatment plan		■			
8	Check if the MD provided reference literature for the non-standard treatment plan	■				▨
9	Look for a literature reference for the non-standard treatment plan (drugs, cycle info)	■	■	■		▨
10	Ask the pharmacist to look for a literature reference for the non-standard treatment plan (drugs, cycle info)	■	■	■		▨
11	Contact MD to provide a literature reference for the treatment plan	■		■		▨
12	Contact MD to resolve differences in dose base between the treatment plan and the orders	■		■		▨
13	Contact MD to enter missing orders	■		■	▨	▨
14	Contact MD to discontinue orders		■	■		
15	Contact MD about discrepancy in dose on orders	■		■		▨
16	Contact MD (or MD and fellow) to review and/or revise fellows order	■	■	■		▨
17	Contact MD to notify about discrepancy in height/weight between treatment plan and EMR			■		
18	Contact Nurse Practitioner to enter missing orders			■	■	
19	Check if clinical note explains different cycle on treatment plan		■			
20	Check if clinical note explains different drug on treatment plan		■			
21	Schedule an additional patient appointment	■	■	■		▨
22	Check for an existing patient appointment that is before the next day of treatment			■	■	
23	Obtain signed order from MD for scans	■				X
24	Tell MA that the patient needs labs during next visit (only if chemotherapy medications are platinum based)	■		■	X	X
25	Tell MA that patient needs scans during next visit					▨
26	Place reminder to self that plan is incomplete (make copy of treatment plan and note on copy, turn folder backwards in box, put note on electronic calendar, put a sticky note on the treatment plan)	■	■	■	▨	▨
27	Attach literature reference to chart			■		
28	Hold treatment plan	■	■	■	▨	▨
29	Wait for information	■		■		▨
30	Delete out-of-date pre-medication orders in the EMR		■			
31	Change timing of pre-medications on orders in EMR (based on wrong timing)		■			
	Total number of steps identified by a method	*17 (55%)*	*16 (52%)*	*21 (68%)*	*3 (10%)*	*1 (3%)*

Table 2: The contributions of each method for eliciting steps for responding to exceptional situations.
Abbreviations: UI = unstructured interviews; O = observations; PSD = partial scenario descriptions; CSD = complete scenario descriptions; FPD = full process description.
Color coding: black cell = identified step; gray cell = confirmed step; cell with X = disputed step; white cell = not addressed step

failed to identify or subsequently confirm the step *confirm the patient is not having concurrent radiation to that specified on the treatment plan (in the EMR)* (step 22 in Table 1). This step is critical, because if it is not performed or is performed incorrectly, the patient might receive a life-threatening amount of radiation. If process elicitation is used to support the development of training materials or materials for real-time process guidance (such as checklists), then failing to elicit such steps might have harmful consequences. The observations also failed to identify critical process steps. Two such steps are steps 20 and 33 in Table 1).

Unstructured interviews were useful for obtaining an initial understanding of the process, for discovering a significant number of process steps (in our study, about 53% of all the identified steps), and for providing a basis for the semi-structured interviews. The observation and semi-structured interview data in Tables 1 and 2 show, however, that even after the significant amount of time and effort spent during the unstructured interviews, the resulting elicited process information had problems—certain steps were not identified during the unstructured interviews and other identified steps were later disputed via one of the subsequent elicitation methods.

Some of the inconsistencies between the unstructured interviews and subsequent methods likely occurred because we initially interviewed only one RN, albeit a senior one, but we subsequently observed and conducted semi-structured interviews with three other RNs. The first RN may have conducted the process differently from the other three RNs or may not have mentioned process steps that seemed obvious to her. Yet, holding time-intensive unstructured interviews with more than one individual may not yield enough additional information to justify the extra time requirements for the interviewers and the interviewees. Furthermore, we observed that during unstructured interviews, process performers tend to think and consequently describe a process in terms of "war stories," which are memorable process executions, as opposed to systematically and exhaustively describing different possible process situations and how such situations are addressed.

Figure 5 shows that the observations identified the highest percentage (about 82%) of normal process steps, whereas the semi-structured interviews using partial scenario descriptions identified the highest percentage (about 68%) of steps for responding to exceptional situations. These results seem to be consistent with the nature of these two elicitation methods. Process performers may be observed to perform steps that they might forget to mention during interviews and thus a higher percentage of normal flow steps get identified via observations than via any interviewing method. At the same time, exceptional situations are not guaranteed to arise during observations and hence the observations identified a lower percentage of steps for responding to exceptional situations compared to the percentages identified by some of the interviewing methods. The high percentage of identified steps for responding to exceptional situations obtained via the semi-structured interviews using partial scenario descriptions could be explained by the ability of this method to focus interviewees on a particular part of the process combined with the fact that twelve of the fifteen partial scenario
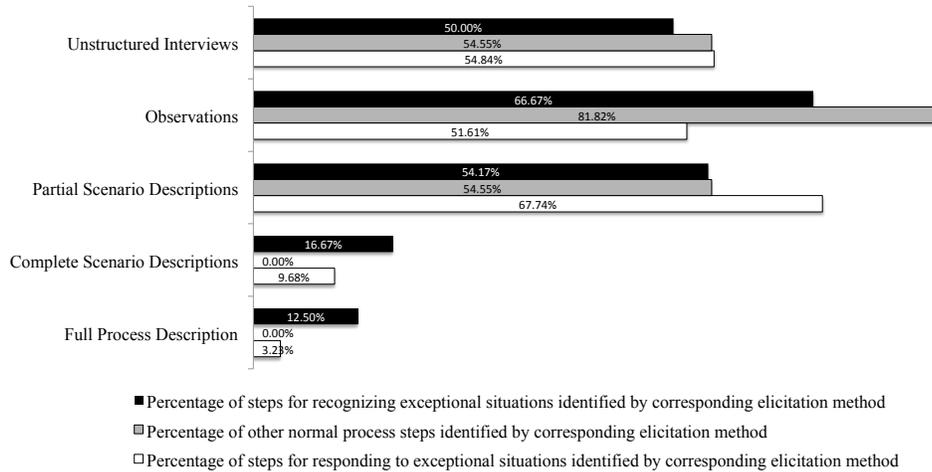
Figure 5: Percentage of steps identified by each elicitation method, broken down by kind of elicited steps. "Other normal process steps" refer to steps that are not steps for recognizing exceptional situations, but are still necessary to carry out the process when no exceptional situations arise.

descriptions we used targeted responses to exceptional situations.

Figure 4 shows that the semi-structured interviews using complete scenario descriptions and the full process description identified a relatively small percentage of the elicited process steps (about 11% and 6% respectively). This low percentage is likely due to the fact that during these elicitation methods the interviewees' cognitive capacity is devoted to verifying already identified steps as opposed to identifying missing steps. The percentage of steps identified during the semi-structured interviews using the partial scenario descriptions is relatively high, most likely because this method gave the RNs an opportunity to fill in a large number of steps to complete very brief partial scenarios.

Another reason for the low percentage (about 11%) of steps identified by the semi-structured interviews using complete scenario descriptions may be the low number of scenarios used. Only three of the possible process scenarios were given to the interviewees (even though these scenarios were rather comprehensive and covered a large portion of the process) in the interest of devoting comparable amount of time to each of the three different kinds of semi-structured interviews. In general, the percentage of steps that this elicitation method could identify is limited by the amount of process coverage achieved by the selected scenarios.

The low percentage (about 6%) of steps identified by the semi-structured interviews using the full process description is surprising given that only about 53% of all elicited steps (all the steps elicited during the unstructured interviews) were included in that description and also given that the RNs were explicitly asked what steps should be added to the process description. This low percentage of identified steps might be attributed to the large cognitive load associated

with reviewing an entire description of a non-trivial process of significant size. Thus, presenting interviewees with a full and complex process description might not be an effective approach for identifying missing information.

Despite the fact that the semi-structured interviews using complete scenario descriptions and the full process description identified a small percentage of all elicited process steps, these two elicitation methods were useful for verifying the steps elicited during the unstructured interviews. As tables 1 and 2 indicate, while reviewing the full process description (which was based on the steps elicited during the unstructured interviews), the RNs confirmed 16 out of the 18 normal process steps and 14 out of the 17 steps for responding to exceptional situations; 2 of the normal process steps and 3 of the steps for responding to exceptional situations were disputed by at least one RN. While reviewing the complete scenario descriptions, the RNs confirmed 15 out of the 18 normal process steps and 5 out of the 17 steps for responding to exceptional situations; 2 of the normal process steps and 1 of the steps for responding to exceptional situations were disputed by at least one RN. Semi-structured interviews seem to be useful for identifying disputed process information because the descriptions used in these interviews make such process information explicit and, thus, easier to notice by process performers.

Note, that the number of steps confirmed or disputed via review of the complete scenario descriptions is lower than the number of steps confirmed or disputed via review of the full process definition, because the complete scenario descriptions presented to the RNs are only a subset of all possible process executions. Increasing the number of complete scenario descriptions (and the number of process steps they cover) presented to interviewees will likely increase the number of steps confirmed or refuted by this elicitation method.

4.2. Disputed steps

In a few instances, individual RNs were inconsistent within their individual responses across the observations and the interviews or with one another about whether particular steps could occur in the process. For instance, step 24 of the normal process steps (*confirm labs have been done*) was identified by RN 1 and RN 2 as never occurring during the treatment plan review process, whereas RN 3 noted that this step is performed if the chemotherapy medications are platinum-based. For step 4 of the steps for responding to exceptional situations (*enter height/weight from the patient chart into the EMR*), RN 1 and RN 2 stated that this step either did not happen or that the original individual who entered the height and weight in the paper chart, typically a medical assistant, would transcribe the information into the EMR.

These disputed steps pose an interesting challenge to process elicitation. They could signify situations where one or more process performers execute the process incorrectly with respect to best-practice guidelines, or they could signify situations where there are acceptable variations for performing a process. Establishing the ground truth about disputed process information often requires a discussion among all disagreeing parties to reconcile the differences and might involve a consultation with best-practice guidelines. In our experience, disputed

Elicitation Method	Time (min.)	# of NSs Identified per 60 min.	# of SRESs Identified per 60 min.	# of NSs Confirmed per 60 min.	# of SRESs Confirmed per 60 min.	# of NSs Disputed per 60 min.	# of SRESs Disputed per 60 min.
Unstructured interviews	360	3	2.8	N/A	N/A	N/A	N/A
Observations	107	14	9	N/A	N/A	N/A	N/A
SSIs with partial scenario descriptions	68	16.8	18.5	N/A	N/A	N/A	N/A
SSIs with complete scenario descriptions	46	5.2	3.9	19.6	6.5	2.6	1.3
SSIs with full process description	42	2.9	4.3	22.9	20	2.9	4.3

Table 3: Total time spent with domain experts for each elicitation method and elicitation method efficiency.
Abbreviations: SSI = semi-structured interviews; NS = normal step; SRES = step for recognizing exceptional situations.

process information is often indicative of misunderstanding or miscommunication between process performers and discovering such disagreements often leads to subsequent process improvements.

4.3. Cost-Benefit Analysis

The second column of Table 3 shows the total time spent with the domain experts (the RNs) for each elicitation method and the columns to the right of the second one show the efficiency of each method in terms of different kinds of elicited process information per unit of time spent with the domain experts. The unstructured interviews identified a substantially smaller number of normal steps and steps for responding to exceptional situations (3 and 2.8, respectively) per 60 minutes spent with the domain experts compared to the observations (14 and 9, respectively) and the semi-structured interviews with partial scenario descriptions (16.8 and 18.5, respectively). All of the semi-structured interviews, however, were based on the unstructured interviews and, thus, the large amount of initial effort spent during the unstructured interviews was amortized over the subsequent semi-structured interviews.

The low efficiency of the unstructured interviews and the relatively high efficiencies of the observations and the semi-structured interviews based on partial scenario descriptions suggest an elicitation approach where materials to support semi-structured interviews are developed based on observations and unstructured interviews are omitted to reduce the cost of the elicitation. Such an approach, however, needs to be used with care and its effectiveness needs to be further investigated as the results in tables 1 and 2 indicate that some important steps (e.g., *check if the MD provided reference literature for the non-standard*

treatment plan) were identified by the unstructured interviews and by no other elicitation method.

The results in table 3 suggest that semi-structured interviews with complete scenario descriptions and full process description are efficient in terms of double-checking already elicited process information. Both of these methods were able to confirm a large number of steps during a relatively short period of time spent with the domain experts.

4.4. Threats to Validity

In the evaluation of the selected process elicitation methods, we made several restrictive decisions regarding the order of method application, the selected process, and the process performers who participated in the evaluation. Additionally, we developed the semi-structured interview materials solely from the unstructured interview findings, and these materials were not updated based on the observational data or between interviews.

The semi-structured interviews were based on information obtained during the unstructured interviews and thus needed to be conducted after the unstructured interviews. The three different kinds of semi-structured interview methods were applied in a specific order to minimize the impact of an interview method on the subsequent interview method. The observations, however, could have been conducted in any order with respect to the unstructured and the semi-structured interviews. The fact that the unstructured interviews were conducted before the observations might have influenced the researchers who conducted the observations by directing their attention to steps discussed during the unstructured interviews. This influence does not appear to be significant, however, as a substantial number of steps that were not identified during the unstructured interviews were identified during the observations. Furthermore, the observed nurses used a think-aloud protocol, which reduced the amount of interpretation of the nurses' actions that the observers needed to do.

One RN participated in the unstructured interviews, and three different RNs all completed the observations and the semi-structured interviews. As discussed in section 4.1, some of the differences between the data obtained via the unstructured interviews and the data obtained via the subsequent elicitation methods might be due to that fact. Similarly, the differences between the results obtained via the observations and the semi-structured interviews might be more substantial if different nurses had participated in the different elicitation methods.

The selected elicitation methods were evaluated on a single process, which we deemed representative of complex HIPs and which was particularly rich in exceptional situations. Furthermore, only one type of process performer, an RN, was involved in the evaluation. Different choices for process, participants, and order of method application could lead to different results. We suspect, however, that regardless of these choices, it would still be beneficial to use multiple elicitation methods. Furthermore, we expect that the kinds of process information that each method is able to discover will not significantly change

due to the characteristics of each method, but recognize that additional studies are needed.

Another potential threat to the validity of the results from this study is the quality of the collected data. Data quality may have been compromised by mistakes/misinterpretations of the collected data by the researchers or by mistakes made by the nurses in terms of conveying process information during the interviews or the observations. To minimize mistakes/misinterpretations by the researchers, interview and observation notes and recordings were carefully kept and reviewed as described in section 2.2. To evaluate the collected data in terms of mistakes made by the nurses while conveying process information to the researchers, we checked whether the elicited steps were identified or confirmed by multiple nurses and multiple elicitation methods and then individually examined the 21 steps that did not fall in this category. We determined that these steps are important snd necessary in the context of chemotherapy treatment plan verification and are thus likely to be valid steps. Another aspect of the quality of the data in this study are the disputed process steps, which are discussed in section 4.

5. Conclusion and Future Work

This paper describes the application of five process elicitation methods—unstructured interviews, observations, and three types of semi-structured interviews—to a complex, safety-critical chemotherapy treatment plan review process. These methods are evaluated in terms of their relative strengths and weaknesses to elicit detailed, precise, and sufficiently complete process information to support rigorous process analysis. Such information might not be necessary for some kinds of analysis, but it is essential for approaches such as model checking and fault-tree analysis. By using these methods, we identified a large number of process steps (66) involved in the process by which RNs review chemotherapy treatment plans, including normal process steps (both steps for recognizing exceptional situations and other steps) and steps for responding to exceptional situations. The contributions of each elicitation method to the understanding of the process by which RNs review chemotherapy treatment plans are also described.

In the future, it would be interesting to explore alternative elicitation methods as well as alternative orderings and combinations of elicitation methods. We explored the ability of the described process elicitation methods to reveal various process steps, but it would also be useful to study their ability to reveal other process information such as the ordering of process steps or the resources used in a process. Another interesting research direction is investigating the ability of the selected elicitation methods to validate formal process models that support the kinds of rigorous process analyses described in section 1. The process elicitation methods explored in this work are domain-independent and thus should be explored in domains other than health care.

Acknowledgments

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Appendix A. Partial Scenario Descriptions

1. A triage MA leaves a treatment plan and orders for a patient in your tray. You confirm that pretesting has been done. What do you do next?
2. A triage MA leaves a treatment plan and orders for a patient in your tray. You confirm that pretesting has been done, confirm existence and not staleness of height/weight data in CIS, confirm treatment plan is created from a careset. What else, if anything, do you do before signing the treatment plan?
3. What steps do you take to verify the doses?
4. A triage MA leaves a treatment plan and orders for a patient in your tray. You notice that labs have not been done for the patient. The chemo drugs for this patient are not platinum-based. How do you proceed?
5. A triage MA leaves a treatment plan and orders for a patient in your tray. You notice that labs have not been done for the patient. The chemo drugs for this patient are platinum-based. How do you proceed?
6. A triage MA leaves a treatment plan and orders for a patient in your tray. You notice that a scan has not been done for the patient. How do you proceed?
7. When you go to check that a patients height and weight have been entered in the CIS, you notice they are missing. How do you proceed?
8. When you go to check that a patient's height and weight have been entered in the CIS, you notice they were taken in another building. How do you proceed?
9. When you go to check that a patient's height and weight have been entered in the CIS, you notice the patient's height and weight measurements are stale. How do you proceed?
10. You receive new height and weight measurements for a patient. There is a 6% change in the dose based on these new values. How do you proceed?
11. While reviewing a patients treatment plan, you notice that the treatment plan was not created from a careset. How do you proceed?
12. While reviewing a patient's treatment plan, you notice that orders are missing for the patient. How do you proceed?
13. While reviewing a patient's treatment plan and orders, you notice the orders were entered by a Fellow. How do you proceed?
14. While verifying doses for a patient, you notice that the height and weight in the treatment plan doesn't match the height and weight in the CIS or in the patient's chart. How do you proceed?
15. While verifying doses for a patient, you calculate the BSA for the patient and notice the calculated dose is greater than the dose in the orders. How do you proceed?

Appendix B. Complete Scenario Descriptions

Appendix B.1. Complete Scenario Description 1

1. You pick up treatment plan and orders that Triage MA has left.
2. You confirm that labs have been done.
3. You confirm that the scans have been done.
4. You confirm existence of patient height/weight data in CIS.
5. You confirm that height/weight are not stale (i.e more than 2 weeks old).
6. You confirm that the treatment plan is created from a careset.
7. You confirm existence of chemo orders for the patient.
8. You confirm that the orders have been entered by an Attending.
9. You verify the doses:
    (a) You confirm that height/weight on treatment plan, in CIS, and in the patient chart all match.
    (b) You calculate BSA using height/weight from CIS.
    (c) You calculate doses using the BSA just calculated and the information form the treatment plan.
    (d) Confirm calculated doses match the ones on the chemo orders.
    (e) Confirm dose base on treatment plan is consistent with doses on orders.
10. Check sticky notes to make sure that everything is completed and it turns out that the labs have been done.
11. You sign the treatment plan.
12. You leave the treatment plan in Triage MAs tray.

Appendix B.2. Complete Scenario Description 2

1. You pick up treatment plan and orders that Triage MA has left
2. You confirm that labs have been done.
3. You confirm that the scans have been done.
4. You confirm existence of patient height/weight data in CIS.
5. You confirm that height/weight are not stale (i.e more than 2 weeks old). You find that height/weight are stale.
6. You tell Clinic MA to schedule an appointment with patient to measure height/weight. You put a sticky note on treatment plan that height/weight need to be remeasured. You stop here and wait until height/weight are remeasured.
7. You get up-to-date height/weight
8. You confirm that the treatment plan is created from a careset. You confirm existence of chemo orders for the patient.
9. You verify the doses:
    (a) You confirm that height/weight on treatment plan, in CIS, and in the patient chart all match.
    (b) You take BSA from the patient record on CIS.
    (c) You calculate doses using the BSA and the information form the treatment plan.
    (d) Confirm calculated doses match the ones on the chemo orders. You sign the treatment plan.
10. You leave the treatment plan in Triage MAs tray.

Appendix B.3. Complete Scenario Description 3

1. You pick up the treatment plan and the orders that the Triage Medical Assistant (Triage MA) has left.
2. You confirm that labs have been done.
3. You discover that a lab result is missing and the drugs are not platinum based.
4. You tell a Medical Assistant (MA) to draw the labs next time the patient comes.
5. You find out that the patient does not have a scheduled appointment and you tell the Triage MA to schedule one.
6. You put a sticky note on the treatment plan to check for the labs before signing the plan.
7. You confirm that the scans have been done.
8. You confirm the existence of patient height/weight data in the CIS.
9. You confirm that the patient's height/weight are not stale (i.e more than 2 weeks old).
10. You confirm that the treatment plan is created from a careset.
11. You confirm the existence of chemo orders for the patient but you find out that they are missing.
12. You call the oncologist to enter the orders in the system.
13. You put a sticky note on the treatment plan to check for the orders.
14. You stop your work on the treatment plan for this patient and wait until the oncologist enters the orders.
15. (in 2 days) You find out that the oncologist has entered the orders for that patient.
16. You confirm that the orders have been entered by an Attending.
17. You verify the doses:
    (a) You confirm that the height/weight on treatment plan, in CIS, and in the patient chart all match.
    (b) You calculate the patient's body surface area (BSA) using height/weight from CIS.
    (c) You calculate doses using the BSA just calculated and the information from the treatment plan.
    (d) You confirm that the calculated doses match the ones on the chemo orders.
    (e) You confirm that the dose base on treatment plan is consistent with the doses on orders.
18. You check all sticky notes to make sure that everything is completed and you confirm that the labs have been done.
19. You sign the treatment plan.
20. You leave the treatment plan in Triage MA's tray.

Appendix C. Full Process Description

1. Pick up treatment plan and the orders.
2. Confirm labs have been done
   (a) If labs haven't been done and the chemo drugs are not platinum-based
       i. Tell MA to draw labs next time when patient comes. (keep tr. plan)
       ii. If the patient does not have a scheduled appointment, either the MA or the Practice RN schedules an appointment.
       iii. Put a sticky note on the treatment plan to check for the labs before signing it.
       iv. Continue to 3 (if not done yet)
   (b) If labs haven't been done and some of the chemo drugs is platinum-based
       i. Tell MA to draw labs next time when patient comes.
       ii. If the patient does not have a scheduled appointment, either the MA or the Practice RN schedules an appointment.
       iii. Stop here and wait for the labs before continuing with the rest of the steps.
3. Confirm scans have been done
   (a) If some of the scans haven't been done
       i. Obtain signed scans order from MD
       ii. Give scans order to an MA (outtake MA, downstairs)
       iii. MA schedules a separate appointment for the scans.
       iv. Put a sticky note on treatment plan to check for scans before signing
       v. Continue to 4
4. Confirm existence of patient's height/weight data in CIS
   (a) If patient height/weight are not entered in CIS but they have been measured in the building
       i. Enter in CIS height/weight from patient chart
       ii. Continue to 5
   (b) If the patient's height/weight haven't been measured in the building
       i. Option 1
          • Schedule an appointment before teaching so that the patient's height/weight will get measured (whoever can reach the patient will schedule it either Triage MA or Practice RN)
          • Continue to 6
       ii. Option 2
          • Indicate height/weight need to be measured during teaching (the patient gets scheduled for teaching (but not chemo) and his/her height/weight get measured then.)
          • Put a sticky note on treatment plan to ensure height/weight remeasured before signing

- Continue to 6

5. Confirm height/weight are not stale.
   (a) If height/weight are stale
      i. Tell clinic MA to schedule an appointment with patient.
      ii. Put a sticky note on the treatment plan that height/weight need to be remeasured
      iii. Wait for height/weight to be remeasured

6. Confirm that treatment plan is created from careset.
   (a) If treatment plan is not from a careset
      i. Check if the doctor gave a reference to the primary literature in the treatment plan.
      ii. If there is no reference
         - (Optionally) look on Google or Pubmed for reference.
         - If there is no reference on Google or PubMed
            – (Optionally) call the Pharmacy and then MD.
            – Continue to 7.
         - Continue to 7.

7. Confirm existence of chemotherapy orders for that patient in CIS.
   (a) If there are no orders
      i. Call MD to enter the orders in the system
      ii. Put a sticky note to check for orders
      iii. Wait until orders are entered

8. If the orders are entered by a Fellow MD, confirm existence of an MD-to-RN order in CIS saying that the Attending MD has approved the Fellow MD's orders.
   (a) If there is no MD-to-RN order
      i. E-mail both attending and fellow MDs.
      ii. Put a sticky note on the treatment plan to ensure that MD-to-RN order is entered before signing.
      iii. Continue to 9.

9. Verify doses (make sure they are correct for the patient's height/weight)
   (a) Confirm height/weight on treatment plan, in CIS, and in the patient chart all match
      i. If they don't match
         - Contact MD and ask how to continue from that point on.
         - Option 1
            – Physician enters an order expressing awareness of the difference in height/weight
            – Continue to 9b
         - Option 2
            – Physician enters new orders with dose change
            – Put a sticky note to check for orders
            – Wait until a new order is entered
            – Continue to 9

(b) Calculate BSA using height/weight from CIS.

(c) Calculate doses using the BSA just calculated and the information from the treatment plan.

(d) Confirm calculated doses match the ones on the chemo orders.

   i. If there is more than 5% discrepancy
      - Contact MD to resolve the discrepancy.
      - Option 1
        – MD says he/she will enter an MD-to-RN order that the current dose is OK
        – Continue to 9e
      - Option 2
        – MD enters new orders with dose change
        – Put a sticky note to check for orders
        – Wait for the new orders
        – Continue to 9d

(e) Confirm dose base on treatment plan is consistent with doses on orders.

   i. If the dose base is not consistent
      - Contact MD to resolve the mismatch.
      - Option 1
        – MD enters new order with correct dose base.
        – Wait until new order is entered
        – Continue to 9e
      - Option 2
        – MD decides to keep the dose on the order
        – MD re-enters the treatment plan and the process starts over.

10. Check sticky notes and make sure that everything is done

   (a) If something is still not done

      i. Continue to 10.

11. Sign treatment plan. (All the pretesting needs to be completed at this point, all issues with height and weight need to be resolved, and doses on the orders need to be verified.)

12. Leave treatment plan in Triage MA's tray.