

The Canadian C-Spine Rule and CT-Head Rule Implementation Studies:
A Psychological Process Evaluation

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ABSTRACT

The Canadian C-Spine (CS) and CT-Head (CT) Rules are tools aimed at improving the accuracy and efficiency of radiography use in emergency departments. This study evaluated whether the Theory of Planned Behaviour (TPB) could explain the inconsistent results from implementation studies of these two rules at 12 Canadian hospitals, where the same intervention resulted in a significant reduction in CS radiography but not CT radiography. It was demonstrated that the TPB model's proposed relationships between constructs and behaviour could explain the ordering of CS but not CT radiography. However, after examining longitudinal changes of the TPB constructs, it was clear that these changes could not explain the changes in CS radiography ordering. Overall, TPB is unlikely to suggest important ways by which to improve radiography use, for CT because its constructs are not related to radiography ordering, and for CS because of high baseline levels of intention to clinically clear.

ACKNOWLEDGEMENTS

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PREFACE

This project encompassed analysis of patient and physician behaviour data already collected through the Canadian C-Spine Rule and CT-Head Rule implementation studies, as well as survey responses from physicians practicing at emergency departments involved in the implementation studies.¹ The implementation study data was obtained from Dr. Stiell's research group and the survey data were obtained from Dr. Brehaut.

TABLE OF CONTENTS

INTRODUCTION	1
OBJECTIVES.....	19
SUMMARY OF PHYSICIAN AND PATIENT SAMPLING	21
Development of TPB-based Surveys.....	21
Administration of TPB-based Surveys within Implementation Studies.....	26
Data Quality of TPB Survey Data	32
Demographic & Employment Characteristics of TPB Survey Respondents	32
Data from Implementation Studies.....	34
Data from Implementation Studies for TPB-based Survey Respondents	37
ANALYSIS	41
Hierarchical Modeling Strategy	41
Objective #1:	
Did the TPB surveys yield reliable and valid measures of the TPB constructs?	43
Objective #2:	
Do TPB constructs predict intention to engage in the target behaviour (clinical clearance without radiography) in this clinical context?	47
Objective #3:	
Can TPB constructs predict actual clinical clearance (as opposed to intention to clinically clear) in this clinical context?	49
Objective #4:	
Did the intervention result in any changes of the TPB constructs?	53
Objective #5:	
Do changes in TPB constructs predict changes in the rate of clinical clearance?	57
RESULTS	61
Objective #1	61
Objective #2	68
Objective #3	70
Objective #4	73
Objective #5	81
DISCUSSION.....	85
Significance	94
Limitations.....	96
Future Research	99
APPENDIX A: C-Spine TPB Survey.....	108
APPENDIX B: CT-Head TPB Survey	110
APPENDIX C: Relevant Variables Collected through Implementation Studies	112

INTRODUCTION

Health care spending is rising faster than economic growth in most developed countries around the world, consuming an ever increasing percentage of their gross domestic product.² Between 1970 and 2003, the percentage of the gross domestic product spent on health care rose from 7.0% to 15.2% in the United States and from 7.0% to 9.9% in Canada. Health care spending in Canada was estimated at over \$180 billion this past year, which translates into 11.9% of the gross domestic product; an all-time high.³ This level of growth in health care spending is unsustainable, as most Canadian provinces will be spending at least half their revenue on health care by 2034 if this trend continues.⁴ New forms of care that are more efficient have the potential to make an enormous difference, and are necessary if we are to mitigate this unsustainable trend in health care spending.

Research funding into how to improve health care is modest in comparison to overall health care spending, but is still substantial. For example, it is estimated that total health research spending reached \$6.6 billion in Canada for the year 2006, and surpassed \$122 billion in the United States for the year 2007.^{5,6} A large portion of this spending is derived from government resources. In Canada, this portion was estimated to exceed \$1.72 billion for the year 2004.⁷ Similar to the trends in health care spending, governmental funding of health research has also been escalating over the last decade, and is projected to increase further. The Canadian Institutes of Health Research (CIHR), the primary federal agency responsible for funding health research, held a budget of only \$250 million at its inception in 2001, but 8 years later its budget was \$962 million, and influential bodies such as the Association of Faculties of Medicine of Canada are recommending that Canada increase its investment in health research by an additional \$350 million.⁸⁻¹⁰ Health research clearly

represents a significant amount of taxpayer money, and given that it is increasing, efforts should be made to ensure that this money is being properly and efficiently utilized.

The bulk of the investment into health care research is concentrated in innovation-based biomedical research.¹¹ This type of research is focused on achieving new and innovative findings; an extremely expensive endeavor. It is estimated that the entire development process for a new drug costs, on average, over \$800 million US.¹² These exorbitant development costs for new pharmaceuticals and technologies necessitate a large return on investment but the actual benefits cannot always be predicted beforehand. The literature is filled with examples of innovations that are quickly adopted only to be later demonstrated as unbeneficial. For example, computer-aided mammography screening which was initially heralded as an innovative step in medicine has now been actually found to be less accurate and may even be associated with increased harms.¹³ In another example, second-generation anti-psychotic drugs have become the drug of choice in treating schizophrenia despite being no more efficacious than their predecessors and 25-40% more expensive.¹⁴ The search for innovation is a costly venture that is not always beneficial.

In contrast to the amount of funding devoted to innovation, relatively little is allocated to the implementation of innovation, resulting in a substantial gap between clinical research and clinical practice.¹⁵ The area responsible for implementing innovation, health services research, only receives 2% of the health care research funding in the United States.¹⁶ This level of funding not only appears miniscule in comparison to the funding allocated to innovation, but also proves to be largely inadequate when one takes into account the time it takes for clinical research to reach clinical practice. According to one estimate, it takes an average of 17 years for new research findings to be reliably used by physicians.¹⁷ Patients are therefore often not receiving the benefit of existing knowledge. For example, one study

showed that Americans do not receive 45 percent of recommended health services for a variety of common conditions.¹⁸ Another study has estimated that 30-40% of patients do not get care of proven effectiveness and 20-30% of patients receive care that is not recommended or harmful.¹⁹ The ample opportunity for improvement within this field suggests that greater impact on overall patient care may be achieved by improving our use of existing knowledge, rather than focusing solely on seeking new breakthroughs.

This gap between clinical research and clinical practice has been labeled the ‘knowledge to action gap’, and has been identified as a major challenge of modern medicine. With over 400,000 articles indexed annually on Medline, it is unrealistic to expect physicians to read and act on all available clinically relevant information that is published.²⁰ To make matters worse, information or technologies can become obsolete over time, as medical knowledge evolves. If we wish to close the gap between clinical research and clinical practice, we cannot continue to simply publish research findings and leave the problem of incorporating this knowledge to users. Instead, an active program of research is required to understand how to translate knowledge into action, so that patients can better benefit from knowledge already in existence.

Knowledge Translation and the Science of Knowledge Translation

Many terms have been used to describe the process by which clinical research is incorporated into clinical practice, but knowledge translation has been the term that has become increasingly used worldwide.²¹ According to the Canadian Institutes of Health Research:

knowledge translation is a dynamic and iterative process that includes synthesis, dissemination, exchange and ethically sound application of knowledge to improve the

health of Canadians, provide more effective health services and products, and strengthen the health care system.²²

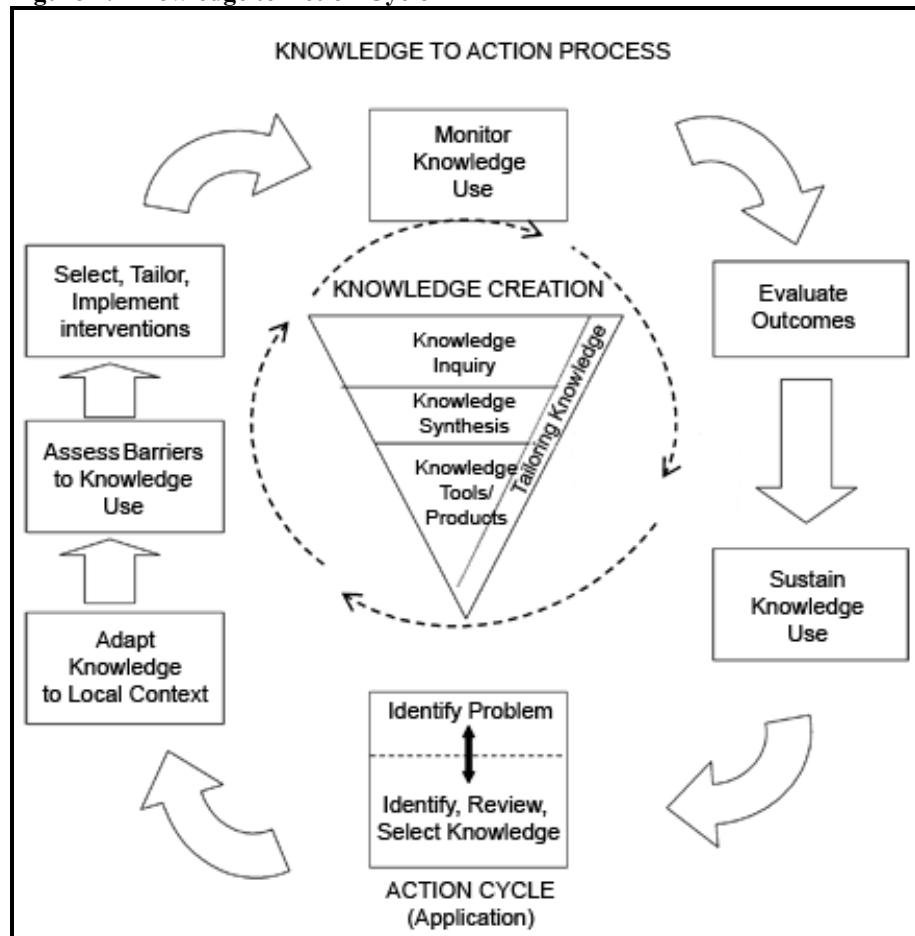
Although various other organizations have derived their own definitions of knowledge translation, the underlying emphasis on active approaches remains a constant throughout these definitions.²³ Passive dissemination of research knowledge through academic journals is not sufficient. There are many different types of active approaches including educational sessions, reminders, and audit and feedback.²⁴ Unfortunately, little is known about the effectiveness of these active approaches to incorporate research knowledge into practice.²⁵ In order to close the gap between clinical research and clinical practice, knowledge translation needs to be scientifically studied by evaluating these active approaches and understanding the causal pathways through which they change behaviour.

Graham and colleagues have provided a framework by which to study knowledge translation known as the knowledge-to-action cycle (KTA; Figure 1).²⁶ This framework is increasingly cited as a way of visualizing the process by which research knowledge can be effectively implemented and sustained in the real world. At the centre of the KTA cycle is the ‘knowledge funnel’, where research knowledge is distilled and tailored towards the targeted audience. In order for individuals to act in a well informed manner for a given context, they need to be provided the relevant information in actionable messages.

Unfortunately, knowledge relating to any particular issue is often spread across many sources and scholastic journals, and therefore may not be in a form conducive to easy use by the intended audience. Key knowledge needs to be identified from the vast literature and synthesized into a form that is intelligible and concise for users. This process involves critical appraisal of individual studies and use of proper statistical techniques to combine their outcomes. Ideally the ‘knowledge funnel’ process leads to the development of a tool

(e.g. guidelines, decision aids) that summarizes the key knowledge for a particular context in an appropriate manner.

Figure 1: Knowledge to Action Cycle



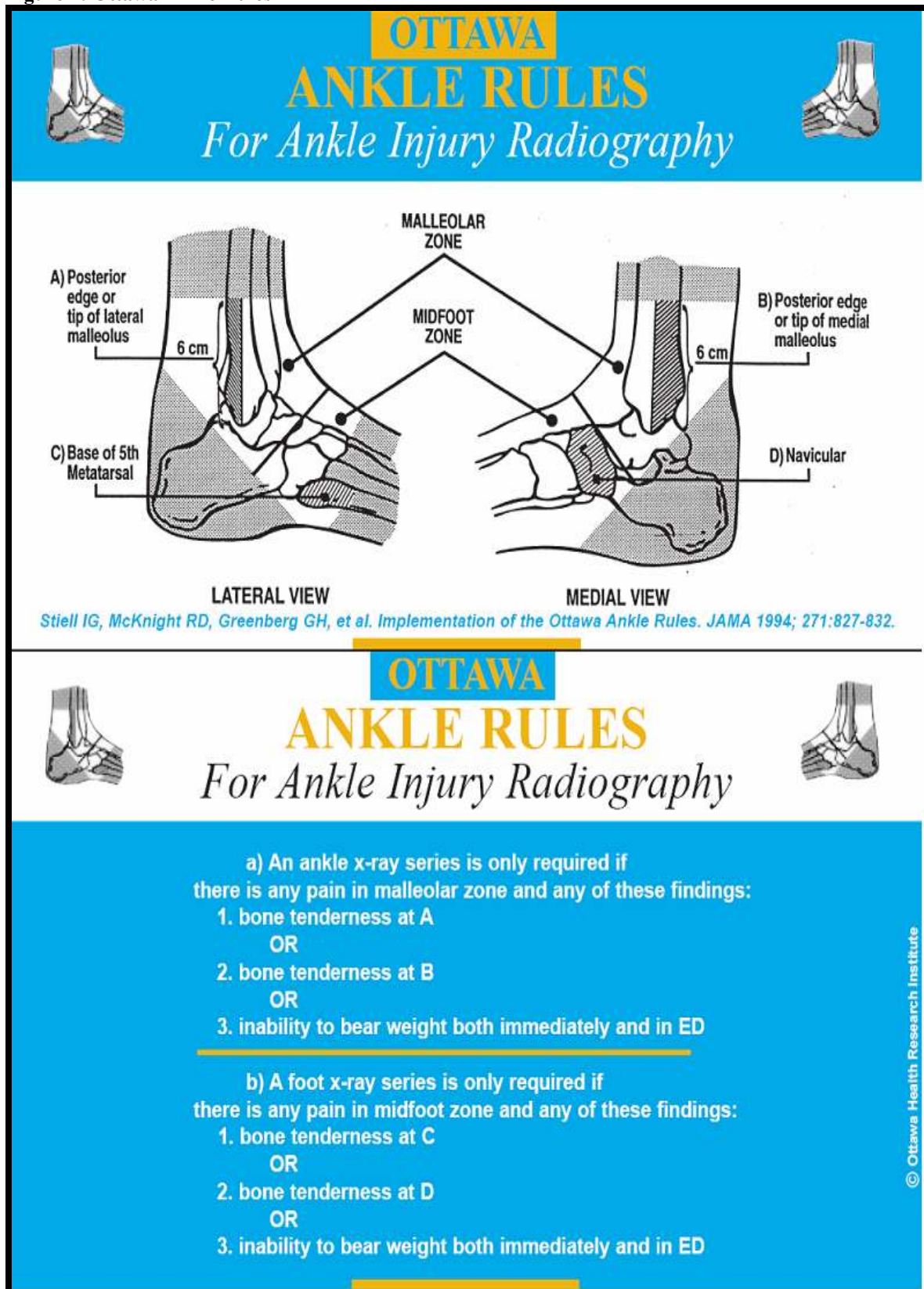
An example of a knowledge translation tool: Clinical Decision Rules

Clinical decision rules (CDRs) are an example of a knowledge translation tool that attempts to facilitate the incorporation of clinical research findings into everyday clinical practice. CDRs aid physicians in making specific, high impact clinical decisions by providing a suggested course of action based on a few key indicators. These indicators are derived from patient histories, physical examinations, or simple diagnostic tests.^{27;28} For

example, the Ottawa Ankle Rules (OAR; Figure 2), is designed to guide emergency department (ED) physicians in deciding whether or not to order radiographs for patients with foot or ankle pain.²⁹ The OAR recommends radiography for a patient based on the existence or absence of a small number of key indicators: pain in the malleolar or mid-foot zone, bone tenderness at one of four distinct locations, and the inability of the patient to bear their own weight (Figure 2). All of these indicators can be observed during a routine examination, allowing physicians to make rapid, accurate, evidence-based decisions. In standardizing the collection and interpretation of clinical data, CDRs aim to reduce the uncertainty and variation involved within the decision making process of clinical practice, and thereby increase the efficiency with which patients receive evidence-based care.^{30;31}

Widespread use of CDRs by physicians can be beneficial to patients and the health care system. For example, it was once habitual for 95% of patients arriving in EDs with foot or ankle pain to undergo radiography, even though no more than 13% of the radiographies demonstrated clinically important fractures.²⁹ The OAR has minimized this unnecessary use of radiography, and thereby also reduced patient exposure to radiation and length of stays in EDs. These benefits have been provided by the OAR without any notable drawbacks, and while simultaneously reducing health expenditures through a reduction in the overall amount of radiography ordered.³² Although individual radiography orders are not expensive items, the sheer bulk of radiography ordered overall is a significant cost for our health care system.²⁹ A multicentre study introducing the OAR into practice at eight hospitals exhibited important reductions in radiographies and wait times, without sacrificing patients' satisfaction or safety.³³ A cost-effectiveness analysis of the OAR estimates that it could save \$730,145 per 100,000 patients in Ontario.³² CDRs represent one method of improving efficiency within health care while simultaneously offering benefits to patients.

Figure 2: Ottawa Ankle Rules



Detailed standards for rigorous development of clinical decision rules have been developed.^{30;34;35} The process begins with evaluating whether there is an inefficient decision making process within clinical practice that would benefit from a clinical decision rule. Once this is established, the derivation stage involves assessing an exhaustive list of potential indicators and the key outcome of interest on a group of patients. Multivariable statistical methods (logistic regression, recursive partitioning) are used to minimize the list of potential indicators by evaluating the independent contribution of each potential indicator towards the outcome of interest.³⁵ The derivation stage should result in a rule that is clinically sensible and easy to use, in order to encourage use by physicians.³⁰ A validation stage evaluates the rule within a different population to ascertain that the associations between predictors and outcomes are robust. This rigorous methodology has been shown to produce statistically sound and sensible rules.³⁰

The Action Cycle of the KTA Framework: Putting a CDR into Action

Once a clinical decision rule is derived and validated, the process shifts from the knowledge funnel of the KTA framework (Figure 1) to the action cycle, where the focus is on the processes that may be necessary for actual application of a CDR. The detailed and rigorous standards of development by no means guarantee that physicians will make use of a CDR.^{36;37} There may be several areas that need to be addressed before a CDR can be incorporated into practice. For example, the knowledge contained within a CDR may not be sufficiently tailored towards a specific set of users, or the environment within which the CDR is to be employed may not facilitate its use. Once such issues are addressed, a KT intervention can be designed to incorporate the CDR into practice. Ideally, use of the CDR is monitored after it is put into practice by the KT intervention, thereby providing feedback

on the extent to which implementation of the CDR has been successful as well as information on gaps, barriers, and facilitators that may have not been previously realized. If the impact is less than desired, it may be necessary to reevaluate the method of implementation that was employed. Ensuring actual and proper use of the CDR could take several iterations. Use of the CDR should continue to be monitored even after a successful implementation, since the circumstances relating to the research knowledge, CDR, or context may change. The goal of the action cycle is to ensure sustained proper use of research knowledge, which means that knowledge translation is an ongoing process rather than an end goal.

An implementation study is one that evaluates the extent to which a chosen KT intervention is actually successful. There are many forms of KT interventions, as well as numerous complex interventions that consist of combinations of these different forms, making the possibilities almost endless. Some may prove more successful than others depending on the context or KT tool being incorporated.²⁶ The success of a KT intervention in implementing a CDR can be evaluated through an implementation study by simultaneously monitoring the use of the CDR and important outcomes of interest. This allows us to evaluate the extent to which a CDR was implemented and the subsequent benefit derived from that level of implementation. An implementation study therefore provides us with a measure of the actual real world impact that can be achieved for a CDR when using a specific KT intervention.

The need for theory in understanding KT interventions:

The results of KT intervention studies have been mixed, demonstrating substantial variation across contexts.³⁸ KT interventions used for CDRs are no exception. Even under

ideal conditions where physicians have every intention to use a CDR and claim to actually use it, proper actual use remains a challenge. For example, 90% of Canadian emergency physicians report actual use of OAR, yet only 42% base their decisions primarily on these rules. Even more concerning is that only 31% of Canadian emergency physicians can actually remember all the components of these rules. Some implementations of these rules have even failed to affect radiography ordering rates at all.³⁹ Further analysis of KT interventions is necessary if we are to reap the potential benefits of CDRs.

It has been argued that a theoretical framework is necessary if we wish to improve our understanding of KT interventions.⁴⁰ Theories provide us with testable hypotheses as well as models that shape the way researchers collect and interpret evidence. Without a theoretical framework, we cannot generalize the results of successful interventions, nor understand the reasons for failed interventions.⁴⁰ Presently, few studies provide any form of theoretical rationale for their method of implementation, with KT interventions often chosen in a haphazard manner. A recent review noted that the vast majority of guideline implementations do not provide any explicit theoretical rationale for their chosen method.⁴¹ As a consequence, we continue with implementations where we may unknowingly be repeating the mistakes of previous studies. There is therefore increasing acknowledgment that testable theories should be used to guide implementation efforts and better our understanding of the factors that act as barriers and facilitators.⁴²

It is important to focus on theories that explain how to change behaviour, since that is the fundamental goal of any KT intervention.^{43;44} We will be focusing on KT interventions intended for emergency department (ED) physicians, a group of professionals who principally work independently of each other. Moreover, the adoption of any KT tool is essentially a physician's individual decision. Thus, it is important to focus on theories

centered on determinants of individual behaviour change. Social cognitive theories meet these requirements by explaining behaviour through the cognitions and thoughts of the individual in relation to their environment.⁴⁵ A significant amount of research within this field has focused on isolating psychological constructs capable of predicting behaviour, thereby providing us with potential targets for KT interventions.

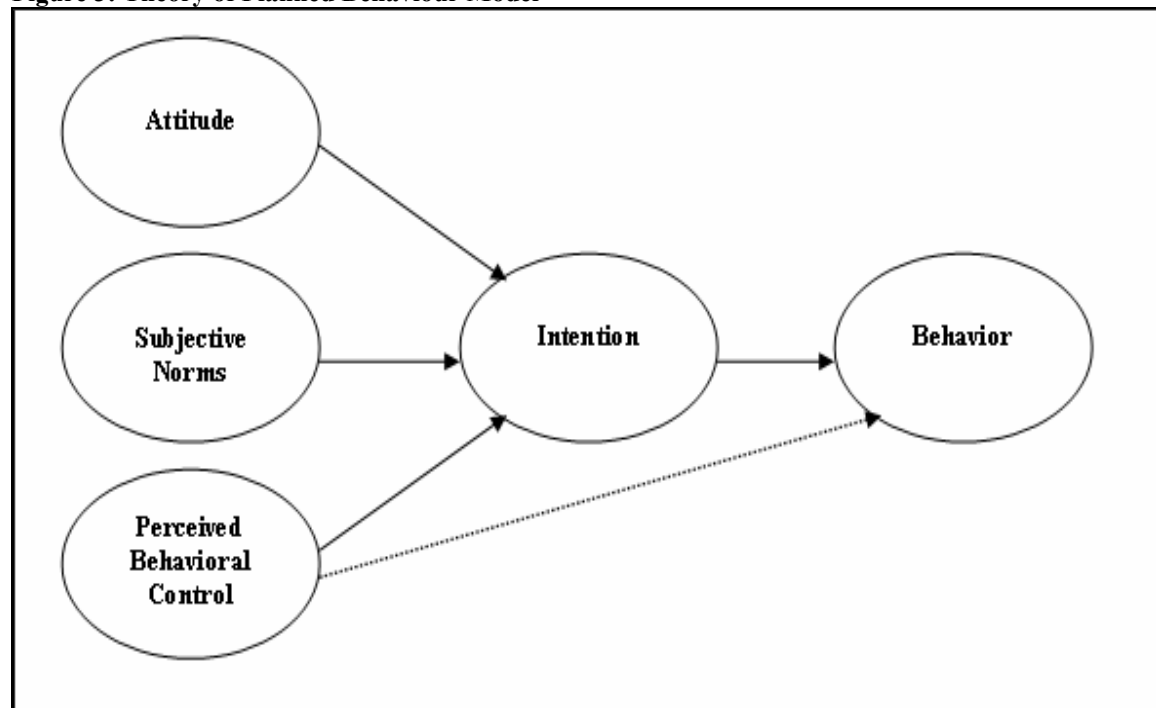
Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB) has been identified as one such social cognitive theory that is useful in understanding the factors that affect behaviour changes in physicians.⁴⁶ It is the most well studied theory in health research, having been tested in many different contexts.⁴⁷ It has been applied to health related behaviours such as drinking habits, sexual practices, and physical activity.⁴⁸⁻⁵¹ TPB has been illustrated to better predict the behaviour of health professionals than other social cognitive theories.⁵² The theory's extensive use and validation in numerous contexts has led to the development of a well defined methodology for creating TPB-related tools.⁴⁷

TPB makes specific unidirectional predictions about relationships between its constructs and behaviour (Figure 3).⁵³ TPB contends that the primary determinant of an individual's behaviour is their intention to perform that behaviour. This intention to engage in a behaviour is a function of attitude, subjective norms, and perceived behavioural control.⁵⁴ The TPB model is illustrated in Figure 3. Attitude refers to the degree to which an individual positively or negatively values their performance of the behaviour. Subjective norms are an individual's perception of whether people of significance to them believe the behaviour should be performed. Perceived behavioural control refers to an individual's perceived ease or difficulty in performing the behaviour. Successful performance of a

behaviour also may depend on having a sufficient level of behavioural control. Thus, the theory also contends that perceived behavioural control can moderate the relationship between intention and behaviour by acting as a proxy for actual control. In this manner, TPB is able to explain both volitional and non-volitional behaviours. Thus, TPB provides a clear model that can be evaluated in relation to a specific behaviour.

Figure 3: Theory of Planned Behaviour Model



Assessing these unidirectional predictions of TPB within a CDR implementation study would allow us to evaluate whether use of CDRs can be explained by the TPB model. The application of TPB constructs to physician use of CDRs represents a unique undertaking. This can be accomplished by running a psychological process evaluation alongside an implementation study. Process evaluations simultaneously capture measures of theoretical constructs and outcomes of interest to assess whether a relationship exists between the constructs and outcomes. Examining these relationships longitudinally at

different points in time allow us to determine whether changes in the constructs affect changes in the outcomes. A TPB-based process evaluation, in this case, provides measures of the TPB constructs during an implementation study. We believe that a TPB-based process evaluation of a CDR implementation study will provide us insight into the uptake of CDRs within clinical practice, and thereby better facilitate our ability to tailor KT interventions towards increasing the uptake of CDRs.

Canadian C-Spine (CS) and CT-Head (CT) Rules: A Unique Opportunity

Although it would be interesting on its own to simply assess whether TPB can explain behaviour within a single implementation study, we have the unique opportunity of assessing TPB by comparing the implementation of two rules. The CS and CT are two rules that purport to improve the efficiency of radiography use in EDs.^{55;56} The CS rule (Figure 4) is aimed at determining whether radiography is required for alert and stable trauma patients who have incurred neck injuries, while the CT rule (Figure 5) is aimed at determining whether radiography is required for patients with minor head injuries.^{56;57} Decisions surrounding whether radiography is required in each of these clinical contexts demonstrate enormous inefficiency at the present time. More than 98% of CS radiography and more than 93% of CT radiography are ordered for patients with no serious injury.^{58;59} It was believed that CDRs could significantly increase the clinical clearance of patients without radiography by minimizing this unnecessary use of radiography. The CS and CT rules were prospectively derived for this purpose and validated using the same methodology demonstrating high sensitivity and reliability.^{57;60}

Figure 4: Canadian C-Spine Rule Pocket Card

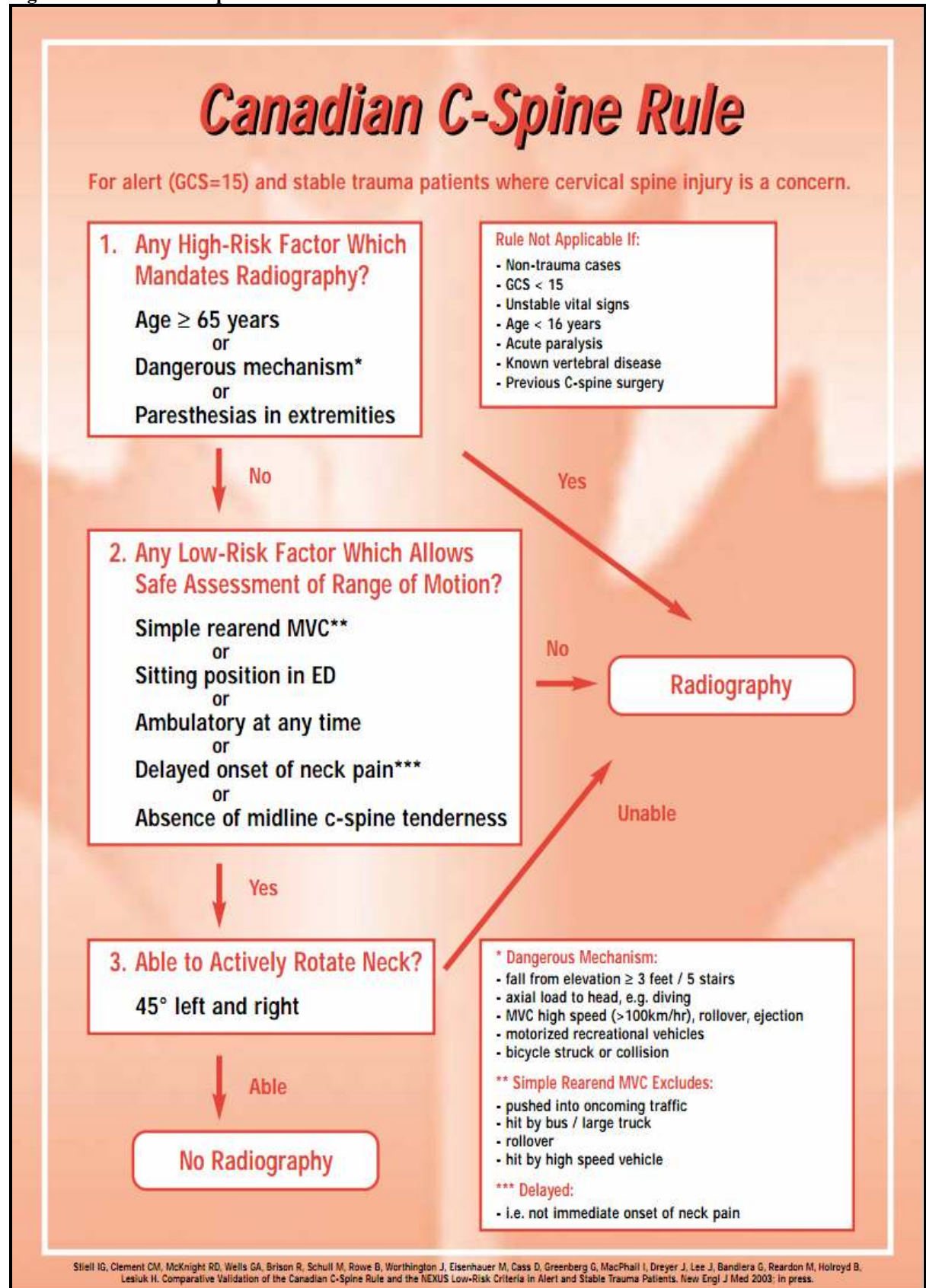


Figure 5: Canadian CT-Head Rule Pocket Card

Canadian CT Head Rule

CT head is only required for minor head injury patients with any one of these findings:

High Risk (for Neurological Intervention)

1. GCS score < 15 at 2 hrs after injury
2. Suspected open or depressed skull fracture
3. Any sign of basal skull fracture*
4. Vomiting ≥ 2 episodes
5. Age ≥ 65 years

Medium Risk (for Brain Injury on CT)

6. Amnesia before impact ≥ 30 min
7. Dangerous mechanism ** (*pedestrian, occupant ejected, fall from elevation*)

***Signs of Basal Skull Fracture**

- hemotympanum, 'raccoon' eyes, CSF otorrhea/rhinorrhea, Battle's sign

**** Dangerous Mechanism**

- pedestrian struck by vehicle
- occupant ejected from motor vehicle
- fall from elevation ≥ 3 feet or 5 stairs

Rule Not Applicable If:

- Non-trauma cases
- GCS < 13
- Age < 16 years
- Coumadin or bleeding disorder
- Obvious open skull fracture

Stiell IG, et al. The Canadian CT Head Rule for Patients with Minor Head Injury. Lancet 2001;357:1391-96.

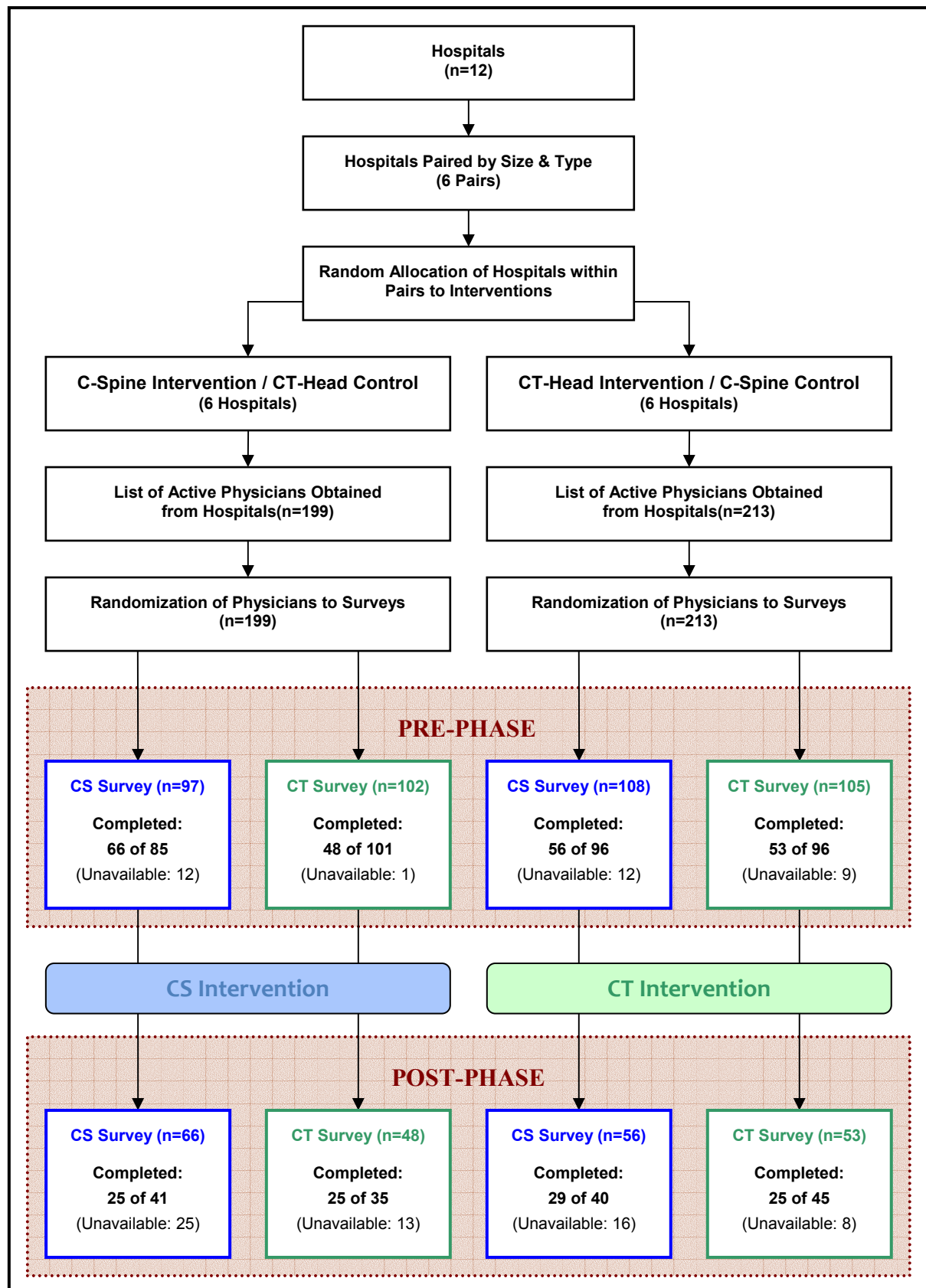
The CS and CT rules each underwent an implementation study. Each of these studies compared outcome measures during ‘pre’ and ‘post’ phases at six pairs of intervention and control hospital EDs.¹ The same hospital pairs were used in each implementation study, except intervention sites in one study served as control sites in the other study and vice versa. Since the CS and CT rules target different forms of radiography and are applied in different clinical contexts, it was assumed that one rule’s intervention would not affect radiography use pertaining to the other rule at the same site. Outcome measures were collected during a pre-phase to establish baseline use of radiography and during a post-phase where the implementation strategies were put into practice at intervention sites. Each phase was approximately one year in duration. The studies used identical KT interventions, which consisted of simple inexpensive strategies that included education (i.e. manuscripts, pocket cards, posters, and a teaching session), and the completion of special requisition forms for radiography relevant to the rule being implemented.⁶¹ These special requisition forms included a reminder of the rule and a check-list of the rule’s criteria that had to be completed for the radiography order to be processed. Physicians could override the rule as long as they indicated their reasoning on the requisition form. It is evident that not only are the rules comparable but the implementation studies are practically identical.

A TPB-based process evaluation was incorporated within each implementation study in an effort to gain a better understanding of the implementation process for CDRs within emergency medicine (Figure 6). A list of active physicians was obtained from participating hospitals during the pre-phase of the implementation studies and randomized either to a CS or CT TPB-based survey, thereby providing intervention and control surveys for each implementation. These surveys were constructed using the same methodology and with the intent of providing measures of the TPB constructs for physicians participating in the studies.

The surveys were administered once in each phase, thereby providing longitudinal measures of the TPB constructs. Only physicians who completed a pre-phase survey were subsequently approached to complete a post-phase survey. The administration of the pre-phase and post-phase surveys was separated by approximately two and half years. We were therefore provided with an opportunity to assess whether changes in TPB constructs account for the uptake of the CDR in each clinical context.

The drastically different results from these implementation studies created a unique opportunity. Despite similar derivations, validations, and implementations, only the CS rule was observed to significantly reduce radiography ordering rates, while the CT rule failed to have any significant impact at all.¹ There was a significant difference in how ordering rates of CS radiography changed from the pre-phase to the post-phase between the intervention and control sites. Intervention sites experienced a relative reduction in CS radiography of 12.8% while control hospitals experienced a relative increase of 12.5%. In contrast, there was no significant difference in how ordering rates of CT radiography changed from the pre-phase to the post-phase between intervention and control sites. Intervention sites experienced a relative increase in CT radiography of 21.2%, while control hospitals experienced a relative increase of 9.9%. These drastically different results are unlikely to be the result of differences in KT strategies (which were very similar) or the decision rules (which were developed to same standards). We are therefore provided with a natural experiment by which to evaluate whether TPB can distinguish between a successful and failed CDR implementation.

Figure 6: TPB Process Evaluation within CDR Implementation Studies



OBJECTIVES

The overall objective of this project is to evaluate the extent to which constructs comprising the Theory of Planned Behaviour account for variability in the uptake of CDRs in EDs. This will be accomplished by examining a series of five objectives:

Objective #1: Did the TPB surveys yield reliable and valid measures of the TPB constructs?

Specifically, we will assess whether:

- I. TPB construct scores are internally consistent;
- II. The TPB construct score of Intention demonstrates validity with lower scores of Intention (to clinically clear without radiography) associated with more reported barriers to CDR use.

Objective #2: Do TPB constructs predict intention to engage in the target behaviour (clinical clearance without radiography) in this clinical context?

Specifically, we will assess whether:

- I. Attitudes that value clinical clearance are associated with higher Intention to clinically clear
- II. Subjective Norms that perceive people of importance to more positively value clinical clearance are associated with higher scores of Intention to clinically clear
- III. Greater Perceived Behavioural Control is associated with higher Intention to clinically clear

Objective #3: Can TPB constructs predict actual clinical clearance (as opposed to intention to clinically clear) in this clinical context?

Specifically, we will assess whether:

- I. Higher Intention to clinically clear is associated with a greater likelihood of performing clinical clearance;

- II. Greater Perceived Behavioural Control is associated with a greater likelihood of performing clinical clearance.

Objective #4: Did the intervention result in any changes of the TPB constructs?

Specifically, we will assess whether:

- I. The intervention that successfully reduced CS radiography also significantly changed one or more of the CS TPB constructs
- II. The intervention that did not successfully reduce CT radiography also did not significantly increase any of the CT TPB constructs

Objective #5: Do changes in TPB constructs predict changes in the rate of clinical clearance?

Specifically, we will assess whether

- I. Changes in Intention and Perceived Behavioural Control predict changes in CS clinical clearance
- II. Changes in Intention and Perceived Behavioural Control predict changes in CT clinical clearance

SUMMARY OF PHYSICIAN AND PATIENT SAMPLING

We have chosen to provide a separate section here that describes the survey methodology and sampling characteristics of physicians and patients. This is not the main analysis of this study which will address the hypotheses, but in order to properly provide an understanding of the context of our results it is important for us to demonstrate how our data were obtained.

Development of TPB-based Surveys

A survey was developed for both the CS and CT clinical contexts. Each survey was designed with the aim of providing measures of the TPB constructs (attitude, subjective norms, perceived behavioural control, and intention) for clinical clearance without radiography in the specific clinical context (CS or CT). These surveys were both derived using Jill Francis' *Constructing Questionnaires based on the Theory of Planned Behaviour*, a widely used manual that provides explicit instruction on how to develop and administer a TPB-based survey.⁴⁷ This methodology suggests that TPB constructs may be measured through direct and indirect measures. Direct measures ask respondents about their overall valuation of each TPB construct whereas indirect measures ask respondents about specific beliefs relating to each TPB construct which are then multiplied by the respective weights the respondent places on the beliefs. For our study, we only used direct measures of TPB constructs because we did not have the resources to collect indirect measures and some literature shows that indirect measures do not increase the level of prediction in regression analysis for TPB.^{47;62} It was also decided that these shorter surveys based only on direct

measures would be more suitable for this study where surveys were to be administered more than once to busy emergency physicians that would not have time for the longer surveys.

The direct measure for each TPB construct was based on three to five relatively standardized survey items. The CS and CT surveys used the same items for direct measures of their TPB constructs except the phrase ‘clinically clearing the C-Spine’ in the CS survey was replaced with the phrase ‘managing patients without CT’ throughout the CT survey. Table 1 describes the stems used for each item and the corresponding anchors of their response scales. The direct measure for attitude used a direct stem (e.g., “Overall, I think that clinically clearing the C-Spine is :”) followed by four items consisting of bipolar adjectives (e.g., “bad practice...good practice”) on seven point response scales. The direct measure for subjective norms involved three items (e.g., “Most of my professional colleagues will clinically clear the C-Spine :”) on seven point response scales which were anchored by phrases of opposite polarity (e.g., “Definitely No...Definitely Yes”), with the scale polarity of one of the items (e.g., “People Important to Me think I should clinically clear the C-Spine :”) reversed in comparison to the other two items. The direct measure for perceived behavioural control involved five items (e.g., “I am confident that I could clinically clear the C-Spine if I wanted to :”) on seven point response scales which were anchored by phrases of opposite polarity (e.g., “Strongly Disagree...Strongly Agree”), with the scale polarity of two items (e.g., “Clinically clearing the C-Spine in these patients is:”) reversed in comparison to the other three items. The direct measure for intention involved four items (e.g., I plan to clinically clear the C-Spine :”) with response scales anchored by phrases of opposite polarity (e.g., “Definitely Do not...Definitely Do”). Three of the four intention items had seven point response scales and the remaining item had a six point response scale. Items for the direct measure of each TPB construct were grouped together

within the survey, while polarity reversal of some response scales was intended to mitigate acquiescence bias.⁶³ These items were the first thirteen items on each survey, and items for the same construct were grouped together. A score for each TPB construct was constructed by realigning the responses of its items to the same polarity and then taking the mean of its items to produce a score out of a maximum of 7.

In addition to the TPB-specific items, the surveys included additional items pertaining to clinical clearance in their respective clinical contexts that went beyond the TPB constructs. Two items were developed to examine potential barriers and facilitators to use of the relevant CDR. This included a checklist of potential barriers so that physicians may indicate with which ones they agreed, as well as a box where physicians could list any barriers not addressed and facilitators that they believed were important. The checklist for each survey was developed by emergency medicine physicians that had taken part in the development of the rules and are displayed in Figure 7 & 8. Other items that were included in the surveys but not used for this project examined a physician's behaviour of clinical clearance; their level of anticipated regret if an important outcome was missed by clinically clearing without radiography; the method by which they used the relevant CDR if it was used; and whether they could identify criteria of the relevant CDR. These additional items that were not used for this project can be viewed within the surveys which are displayed in Appendix A and B.

Table 1: Description of TPB Construct Items from Surveys

TPB Construct	Survey Item Stems (‘C-Spine Version’ / ‘CT-Head Version’)	Response Scale Anchors
Attitude	- Overall, I think ‘<i>clinically clearing the C-Spine</i>’ / ‘<i>managing patients without CT</i>’ is: - Overall, I think ‘<i>clinically clearing the C-Spine</i>’ / ‘<i>managing patients without CT</i>’ is: - Overall, I think ‘<i>clinically clearing the C-Spine</i>’ / ‘<i>managing patients without CT</i>’ is: - Overall, I think ‘<i>clinically clearing the C-Spine</i>’ / ‘<i>managing patients without CT</i>’ is:	Bad Practice / Good Practice Harmful / Beneficial Negative / Positive wrong thing to do / right thing to do
Subjective Norms	- Most of my Professional Colleagues will ‘<i>clinically clear the C-Spine</i>’ / ‘<i>manage patients without CT</i>’: - People Important to Me think I should ‘<i>clinically clear the C-Spine</i>’ / ‘<i>manage patients without CT</i>’: - The Canadian Association of Emergency Physicians would:	Definitely No / Definitely Yes * Definitely Should / Definitely Should Not Definitely Disapprove / Definitely Approve
Perceived Behavioural Control	‘<i>Clinically clearing the C-Spine</i>’ / ‘<i>Managing patients without CT</i>’ is: - What is the likelihood that you will be able ‘<i>clinically clear the C-Spine</i>’ / ‘<i>managing patients without CT</i>’ is: - I am confident that I could ‘<i>clinically clear the C-Spine</i>’ / ‘<i>manage patients without CT</i>’ if I wanted to: - There are factors outside my control prevent me from ‘<i>clinically clearing the C-Spine</i>’ / ‘<i>managing patients without CT</i>’: - How much control do you have over ‘<i>clinically clearing the C-Spine</i>’ / ‘<i>managing patients without CT</i>’:	* Easy / Difficult Very Unlikely / Very Likely Strongly Disagree / Strongly Agree * Strongly Agree / Strongly Disagree No Control / Complete Control
Intention	- I intend to ‘<i>clinically clear the C-Spine</i>’ / ‘<i>managing patients without CT</i>’: - I want to ‘<i>clinically clear the C-Spine</i>’ / ‘<i>manage patients without CT</i>’: - I plan to ‘<i>clinically clear the C-Spine</i>’ / ‘<i>manage patients without CT</i>’: - My desire to ‘<i>clinically clear the C-Spine</i>’ / ‘<i>manage patients without CT</i>’:	Definitely Do Not / Definitely Do Definitely Do Not / Definitely Do Definitely Do Not / Definitely Do No Desire / Very Strong

* Polarity of anchors are reversed relative to anchors of other items used for the same TPB construct

Figure 7: Checklist of Potential Barriers in CS Survey

☐ I am not comfortable evaluating rotation	☐ Services like Trauma and Neurosurgery will order the x-rays anyway
☐ I believe the studies and evidence supporting clearance are flawed	☐ I believe rules governing clearance are not safe for patients
☐ I am too busy ; clinical clearance takes too much time and effort	☐ I resent the concept of rules and guidelines
☐ I see no important advantages to clinical clearance	☐ I forget the details of how to apply the rules
	☐ I prefer the NEXUS Criteria to the CCR

Figure 8: Checklist of Potential Barriers in CT Survey

☐ I believe the studies and evidence supporting managing without CT are flawed	☐ Services like Trauma and Neurosurgery will order the CT anyway
☐ I am too busy; managing without CT takes too much time and effort	☐ I believe rules governing management without CT are not safe for patients
☐ I see no important advantages to managing without CT	☐ I resent the concept of rules and guidelines
	☐ I forget the details of how to apply the rules

Demographic and practice details were obtained at the end of each survey to provide information on the sample of physicians that would complete the surveys. There were three demographic questions that asked for the physician's sex, age, and year of medical school graduation. Four survey questions asked for employment information including employment status, years of work in emergency medicine, medical credentials, and average number hours worked in emergency medicine each week. The TPB-based surveys produced from this process were each two pages in length and could be completed in less than 10 minutes.

The surveys were piloted within only the study's research team but given the extensive use of the TPB methodology from which the CS and CT surveys were derived, it is unlikely that more extensive piloting would have dramatically changed the surveys. Furthermore, piloting the surveys at any of the twelve hospitals where the implementations were to take place would have contaminated the sites, and also reduced the number of

physicians who would be eligible to subsequently partake in the surveys during the implementation studies.

Administration of TPB-based Surveys within Implementation Studies

Physicians at each of the hospitals involved in the implementation studies were identified to partake in the TPB-based surveys (Figure 6). Since both implementation studies used the same hospitals, it was important to ensure that physicians at each hospital only completed one of the two TPB-based surveys. A list of active physicians was obtained from each of the hospitals during the pre-phase of the implementation studies. There were 199 physicians in hospitals that had been assigned to the CS intervention arm and 213 physicians in hospitals that had been assigned to the CT intervention arm. These physicians were assigned a random number between 0 and 1 using the Microsoft Excel uniform random number generator. Physicians given numbers less than or equal to 0.5 were assigned to receive a CS survey and those with numbers above 0.5 were assigned to receive a CT survey. In the CS intervention arm, 97 physicians were randomized to a CS survey and 102 physicians were randomized to a CT survey. In the CT intervention arm, 108 physicians were randomized to a CS survey and 105 physicians were randomized to a CT survey. This process provided us with intervention and control groups for each survey.

Physicians were approached by site coordinators during the pre-phases of the implementation studies to participate in their assigned surveys. 122 (66 Intervention, 56 Control) of the 205 (97 Intervention, 108 Control) physicians randomized to receive a CS survey subsequently completed their respective pre-phase survey. 24 of the physicians randomized to receive a CS survey were not active at the hospitals at the time of the pre-phase survey (12 Intervention, 12 Control). The exclusion these physicians resulted in a

67% (122 of 181) response rate for the CS pre-phase survey. 101 (53 Intervention, 48 Control) of the 207 (105 Intervention, 102 Control) physicians randomized to receive a CT survey subsequently completed their respective pre-phase survey. 10 of these physicians randomized to receive a CT survey were not active at the hospitals at the time of the pre-phase survey (9 Intervention, 1 Control). The exclusion of these physicians resulted in a 51% (101 of 197) response rate for the CT pre-phase survey. These response rates are most likely conservative estimates of the true participation rates as the denominators may include additional physicians who at the time of survey administration, were active but did not actually receive their assigned survey.

The TPB-based surveys were administered once again in the post-phase of the implementation studies to provide us with longitudinal measures of the TPB constructs (Figure 6). Only physicians who completed a pre-phase survey and who were still active at the hospitals at the time of the post-survey were eligible to complete a post-phase survey. Physicians were to complete the same TPB-based survey (CS or CT) in the post-phase that they had completed in the pre-phase. Site coordinators were once again responsible for approaching eligible physicians to participate in their assigned surveys. Physicians were sent pre-notification letters a week before they were to be approached by site coordinators. The administration of the pre-phase and post-phase surveys was separated by approximately two and half years. 54 (25 Intervention, 29 Control) of the 122 physicians who completed CS pre-phase surveys subsequently completed CS post-phase surveys. 41 (25 Intervention, 16 Control) of the physicians who were to complete a CS post-phase survey were unavailable. The exclusion of these physicians resulted in a 67% (54 of 81) response rate for CS post-phase surveys. 50 (25 Intervention, 25 Control) of the 101 physicians who completed CT pre-phase surveys subsequently completed CT post-phase surveys. 21 (8 Intervention, 13

Control) of the physicians who were to complete a CT post-phase surveys were unavailable. The exclusion of these physicians resulted in a 63% (50 of 80) response rate for the CT post-phase surveys. As in the pre-phase administration, response rates are likely conservative estimates of the true participation rates since we are not certain that non-responders actually received their survey.

Figure 9 displays the cluster characteristics for the TPB-based process evaluation of the CS study, which consisted of the physicians randomized to the CS survey. These physicians were clustered within each of the 6 hospitals of the CS intervention and control groups. On average, CS intervention and control hospitals each respectively contained 16.2 and 18.0 physicians that had been randomized to a CS survey. These clusters ranged in size from 6 to 29 in the intervention hospitals and 10 to 29 in the control hospitals. Each cluster decreased in size with the administration of the CS pre-phase surveys, as drop-outs were observed in each hospital. Physicians who had completed their CS pre-phase survey were clustered within each of the 6 hospitals of the CS intervention and control groups. On average, CS intervention and control hospitals each respectively contained 11.0 and 9.3 physicians who had completed a CS pre-phase survey. These clusters ranged in size from 5 to 20 in the intervention hospitals and from 1 to 21 in control hospitals. Each cluster was further reduced in size with the administration of the CS post-phase surveys, as drop-outs were again observed in each hospital. Physicians who completed their CS post-phase survey were clustered within 5 of the 6 hospitals of the intervention group, and within 4 of the 6 hospitals of the control group. These CS intervention and control hospitals each respectively contained on average 4.2 and 4.8 physicians who had completed a CS post-phase survey. Clusters ranged in size from 0 to 10 in the intervention group and 0 to 10 in the control

group. There was therefore some notable loss of hospital clusters in the TPB-based process evaluation of the CS study.

Figure 10 displays the cluster characteristics for the TPB-based process evaluation of the CT study, which consisted of the physicians randomized to the CT survey. These physicians were clustered within each of the 6 hospitals of the CT intervention and control groups. On average, CT intervention and control hospitals each respectively contained 17.5 and 17.0 physicians that had been randomized to a CT survey. These clusters ranged in size from 12 to 23 in the intervention hospitals and 8 to 23 in the control hospitals. Each cluster was reduced in size with the administration of the CT pre-phase surveys, as drop-outs were observed in each of the hospitals in the intervention group, and in 5 of the hospitals in the control group. Physicians who completed their CT pre-phase survey were clustered within each of the 6 hospitals in the CT intervention group, but in only 5 of the 6 hospitals in the CT control group. On average, these CT intervention and control hospitals each respectively contained 8.8 and 8.0 physicians who had completed a CT pre-phase survey. Clusters ranged in size from 6 to 13 in the intervention hospitals and from 0 to 15 in the control hospitals. Each cluster was further decreased in size with the administration of the CT post-phase surveys, as additional drop-outs were observed in each of the hospitals in the intervention group, and in 4 of the hospitals in the control group. Physicians who completed their CT post-phase survey were clustered within each of the 6 hospitals in the CT intervention group, but in only 5 of the 6 hospitals in the CT control group. These CT intervention and control hospitals each respectively contained 4.2 physicians who had completed a CT post-phase survey. Clusters ranged in size from 1 to 9 in the intervention group and from 0 to 7 in the control group. There was therefore some notable loss of clusters in the TPB-based process evaluation of the CT study.

Figure 9: TPB-Based Process Evaluation of CS Implementation Study

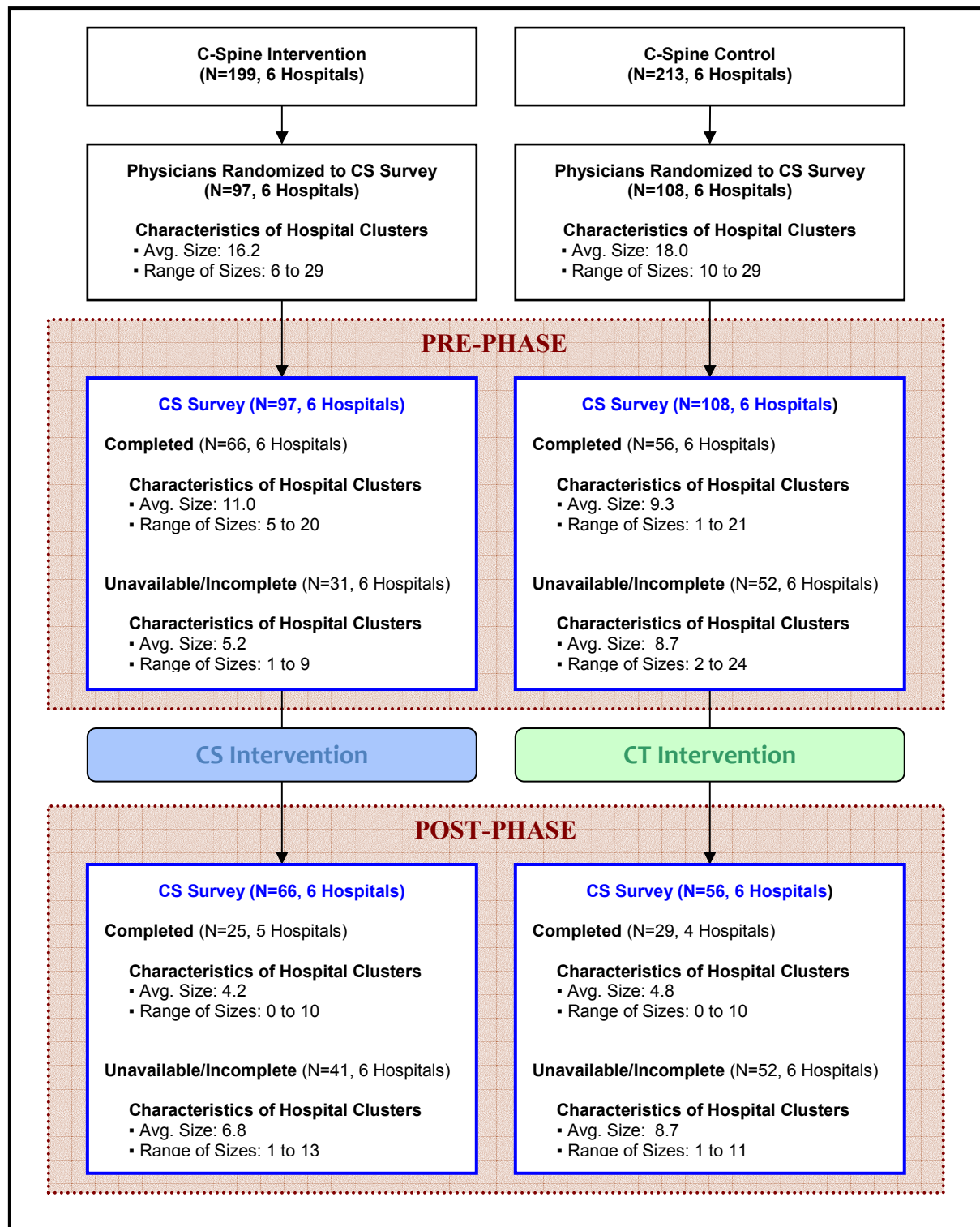
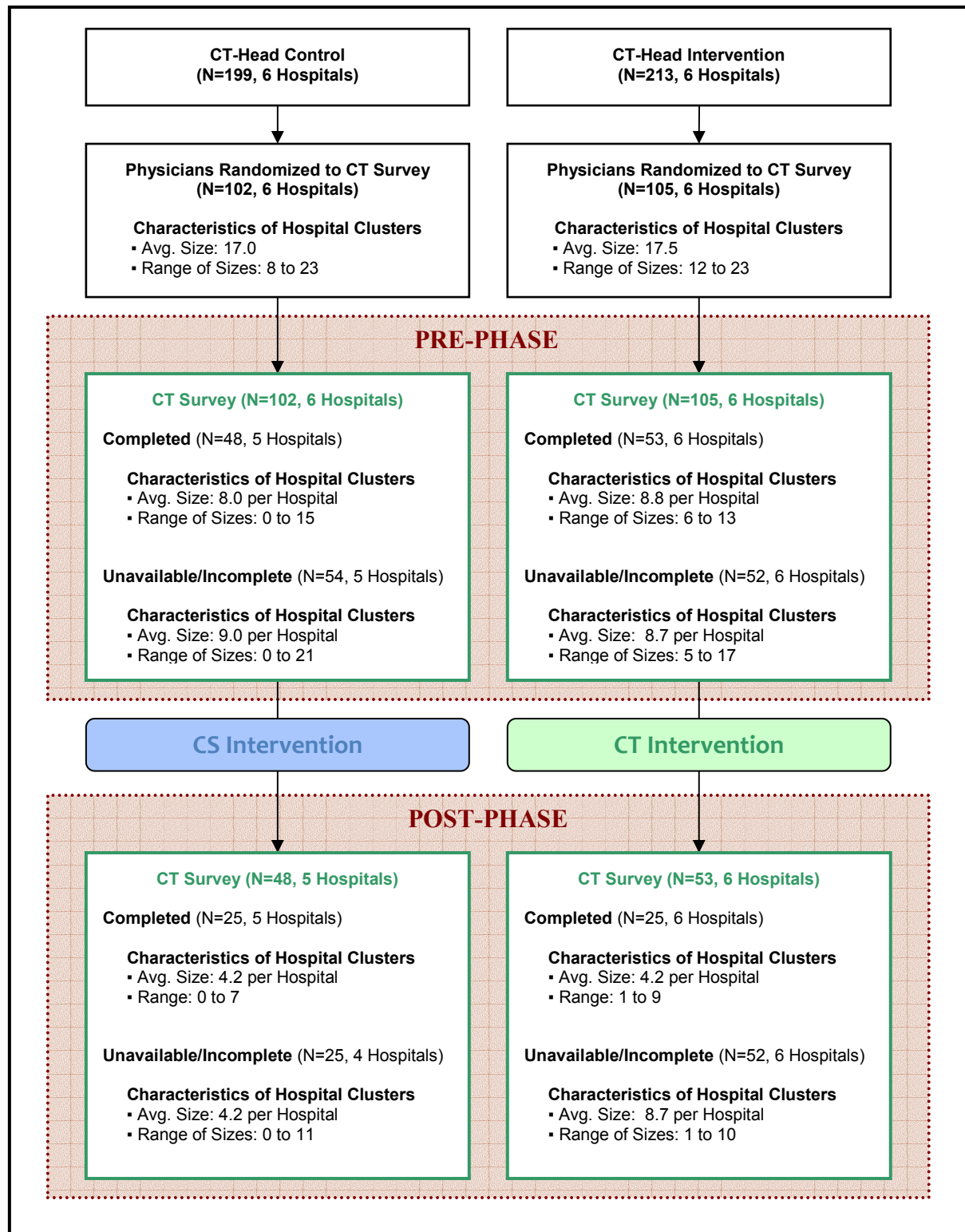


Figure 10: TPB-Based Process Evaluation of CT Implementation Study



Data Quality of TPB Survey Data

Datasets containing survey responses were obtained and a subset of respondents to each TPB-based survey (CS, CT) was compared against their original surveys for accuracy. The subset of respondents for each survey consisted of a random 10% sample of respondents that was generated by SPSS. 99.9% of the 780 entries in the 10% sample of the CS TPB Survey and 99.8% of the 637 entries in the 10% sample of the CT TPB surveys were accurate in comparison to the original surveys. Any found discrepancies were corrected in the master dataset, but the high agreement rate was taken as evidence that full data re-entry wasn't required.

Demographic & Employment Characteristics of TPB Survey Respondents

Demographic and employment characteristics were obtained from physicians who participated in the TPB pre-phase surveys and are displayed in Table 2. Respondents had a mean age of 40.5 and 38.5 in the CS and CT surveys respectively. 77.9% of the respondents to the CS surveys and 79.2% of the respondents to the CT surveys were male. Respondents to the CS survey had on average graduated from medical school 13.7 years beforehand, had been practicing emergency medicine for 10.6 years, and worked on average 27 hours per week in the ED. Respondents to the CT surveys had on average graduated from medical school 12.0 years beforehand, had been practicing emergency medicine for 9.3 years, and worked on average 29.9 hours per week in the ED. Among the CS survey respondents, 10.7% had family physician accreditation (CCFP), 45.5% had family physician accreditation with additional emergency medicine training (CCFP (EM)), 43.8% had emergency medicine accreditation (FRCPC), and 14.3% had American emergency medicine accreditation (Dip

ABEM). Among the CT survey respondents, 10.4% had family physician accreditation (CCFP), 45.8% had family physician accreditation with additional emergency medicine training (CCFP (EM)), 42.7% had emergency medicine accreditation (FRCPC), and 11.5% had American emergency medicine accreditation (Dip ABEM). Characteristics of survey participants were similar for the C-Spine and CT-Head surveys.

Table 2: Demographic & Employment Characteristics of TPB Survey Participants

Variables	C-Spine (N=122)	CT-Head (N=101)
Age (Mean (SD))	40.5 (8.6)	39.5 (9.1)
Male (% (n))	79.3 (96)	79.2 (80)
Years since Medical School Graduation (Mean (SD))	13.7 (9.2)	13.0 (8.1)
Years Practicing Emergency Medicine (Mean (SD))	10.6 (8.4)	9.3 (7.7)
Hours per Week treating ED patients (Mean (SD))	27.0 (12.1)	29.9 (9.5)
Emergency Credentials (% (n))		
CCFP	10.7 (12)	10.4 (10)
CCFP (EM)	45.5 (51)	45.8 (44)
FRCPC	43.8 (49)	42.7 (41)
Dip ABEM	14.3 (16)	11.5 (11)

Data from Implementation Studies

Patient and Physician behaviour data were attained in the form of two SPSS datasets, one for each implementation study. Each dataset row represented a patient case that satisfied the inclusion criteria of the implementation study and was treated during the implementation study's specified period of duration at one of the 12 selected hospitals. Patient-specific logistical information included the attending physician, the hospital where patient was treated, the phase within the implementation study when the patient was treated, whether the patient arrived by ambulance, radiography ordered for the patient, and whether the patient was admitted to the hospital. Variables collected through the implementation study that were relevant to this project are described in Appendix C.

Table 3 describes the CS implementation study which involved 11826 (6897 Intervention, 4929 Control) patient cases and 483 physicians (238 Intervention, 245 Control) at twelve Canadian hospital emergency departments. The table provides a breakdown of the number of physicians and number of patients for each phase and group of the study. No physicians were excluded from participating in the study, nor were physicians required to participate in both phases of the study. As a result, many physicians only participated in one of the study's two phases. Our data shows that only 297 (155 Intervention, 142 Control) of the 483 physicians in the study contributed at least one eligible patient in both pre and post phases of the study, suggesting a significant amount of turnover in personnel within the study. Thus, there are physicians who entered the implementation study after the randomization to the TPB-based surveys, as well as physicians who were no longer involved after the pre-phase of the study.

Table 3: Distribution of Physicians and Patients within CS Implementation Study

Study Arm	Intervention Group (6 Hospitals)		Control Group (6 Hospitals)	
	Pre-Phase	Post-Phase	Pre-Phase	Post-Phase
Physicians per Hospital				
Minimum	14	15	21	24
Mean	32.2	33.3	32.5	32.0
Maximum	46	45	52	52
Total Physicians	193	200	195	192
(Physicians that treated cases in both phases)	(155)	(155)	(142)	(142)
Patients per Physician				
Minimum	1	1	1	1
Mean	16.9	18.1	12.4	13.1
Maximum	69	90	68	52
Total Patients	3268	3629	2413	2516
(Treated by Physicians who Participated in both phases)	(2987)	(3289)	(2231)	(2348)

Table 4 describes the CT implementation study which involved 4531 (2579 Intervention, 1952 Control) patient cases and 434 physicians (220 Intervention, 214 Control) at twelve Canadian hospital emergency departments. The table provides a breakdown of the number of physicians and number of patients for each phase and group of the study. As with the CS implementation study, no physicians were excluded from participating in the CT implementation study, nor were physicians required to participate in both phases of the CT

implementation study. Our data shows that only 253 of the 434 physicians in the CT implementation study contributed at least one eligible patient in both phases of the study, suggesting a significant amount of turnover also in this study. Thus, similar to the CS implementation study, there are physicians who entered the CT implementation study after the randomization to the TPB-based surveys, as well as physicians who were no longer involved after the pre-phase of the study.

Table 4: Distribution of Physicians and Patients within CT Implementation Study

Study Arm	Intervention Group (6 Hospitals)		Control Group (6 Hospitals)	
	Pre-Phase	Post-Phase	Pre-Phase	Post-Phase
Physicians per Hospital				
Minimum	17	18	15	16
Mean	29.2	29.2	28.0	28.2
Maximum	45	41	44	42
Total Physicians	175	175	168	169
(Physicians that treated cases in both phases)	(130)	(130)	(123)	(123)
Patients per Physician				
Minimum	1	1	1	1
Mean	6.0	8.7	5.2	6.4
Maximum	43	62	27	29
Total Patients	1048	1531	877	1075
(Treated by Physicians who Participated in both phases)	(943)	(1340)	(765)	(957)

Data from Implementation Studies for TPB-based Survey Respondents

Figure 11 describes the distribution of CS patients among the physicians who were randomized to a CS survey. Whether behaviour data was collected on a physician within either implementation study was dependent on whether they actually treated an eligible patient for the study in question. The TPB surveys were administered to physicians deemed to be active at the participating hospitals but it was not assured that they would subsequently treat any eligible patients within either phase. 63 of the 66 physicians in the CS intervention group who completed a CS pre-phase survey treated eligible CS patients in the pre-phase, signifying that there was no behaviour data for 3 respondents with completed pre-phase surveys. 54 of the 56 physicians in the CS control group who completed a CS pre-phase survey treated eligible patients in the pre-phase, signifying that there was no behaviour data for 2 respondents with completed pre-phase surveys. On the other hand, several physicians who had not completed their surveys also did not have any behaviour data in the pre-phase, and therefore would not have contributed to any analysis of the behaviour of interest even if they had completed the survey. 24 of the 25 physicians in the CS intervention group who completed a CS survey in both phases also treated eligible CS patients in both phases, signifying that 1 respondent with completed CS surveys in both phases did not treat patients in both phases. 28 of the 29 physicians in the CS control group who completed a CS survey in both phases also treated eligible CS patients in both phases, signifying that 1 respondent with completed CS surveys in both phases did not treat patients in both phases. Our CS survey respondents therefore may represent physicians who are either more active or regular at their hospitals.

Figure 11: Distribution of CS Patient Cases among Physicians Randomized to CS Surveys

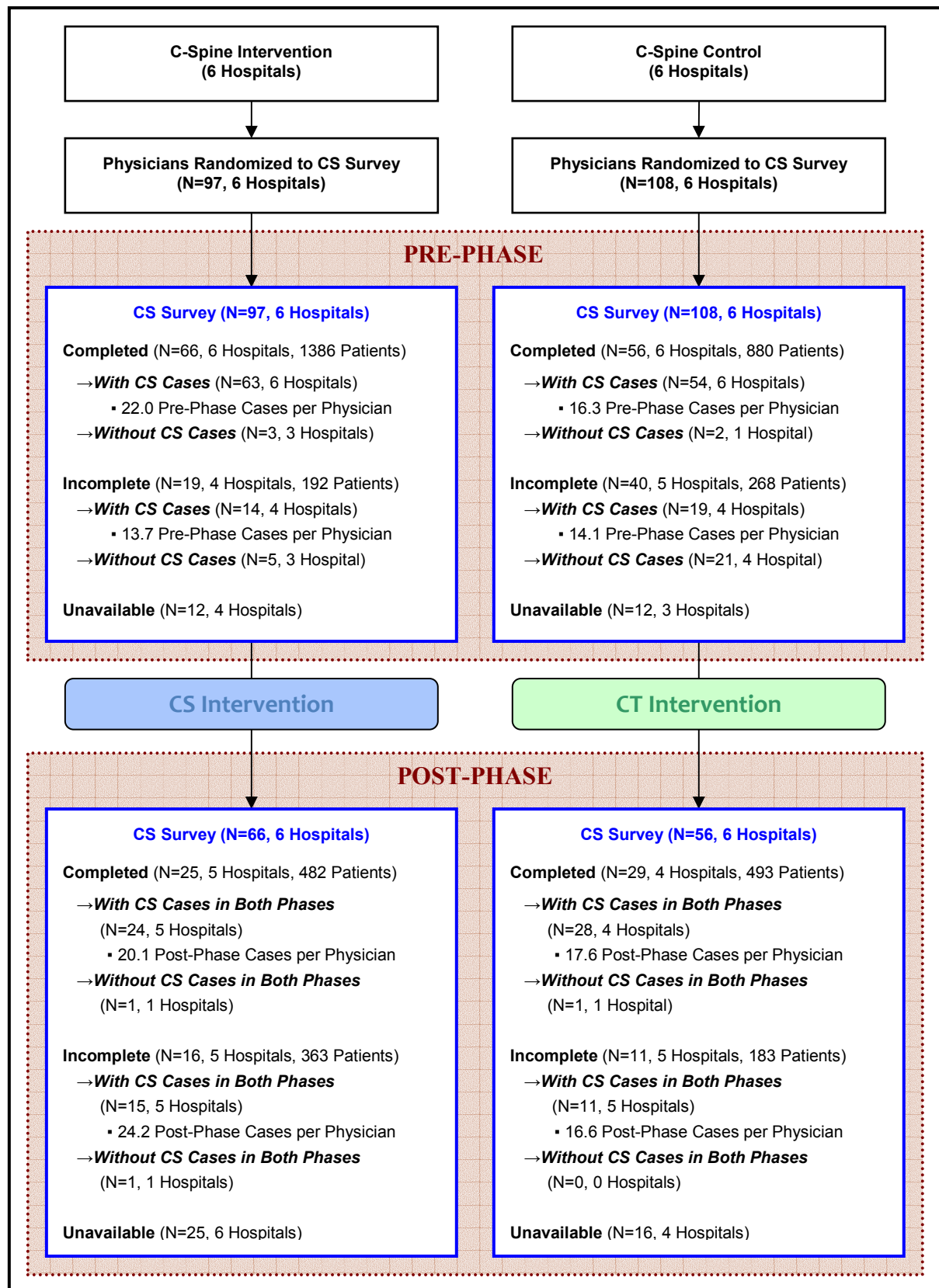
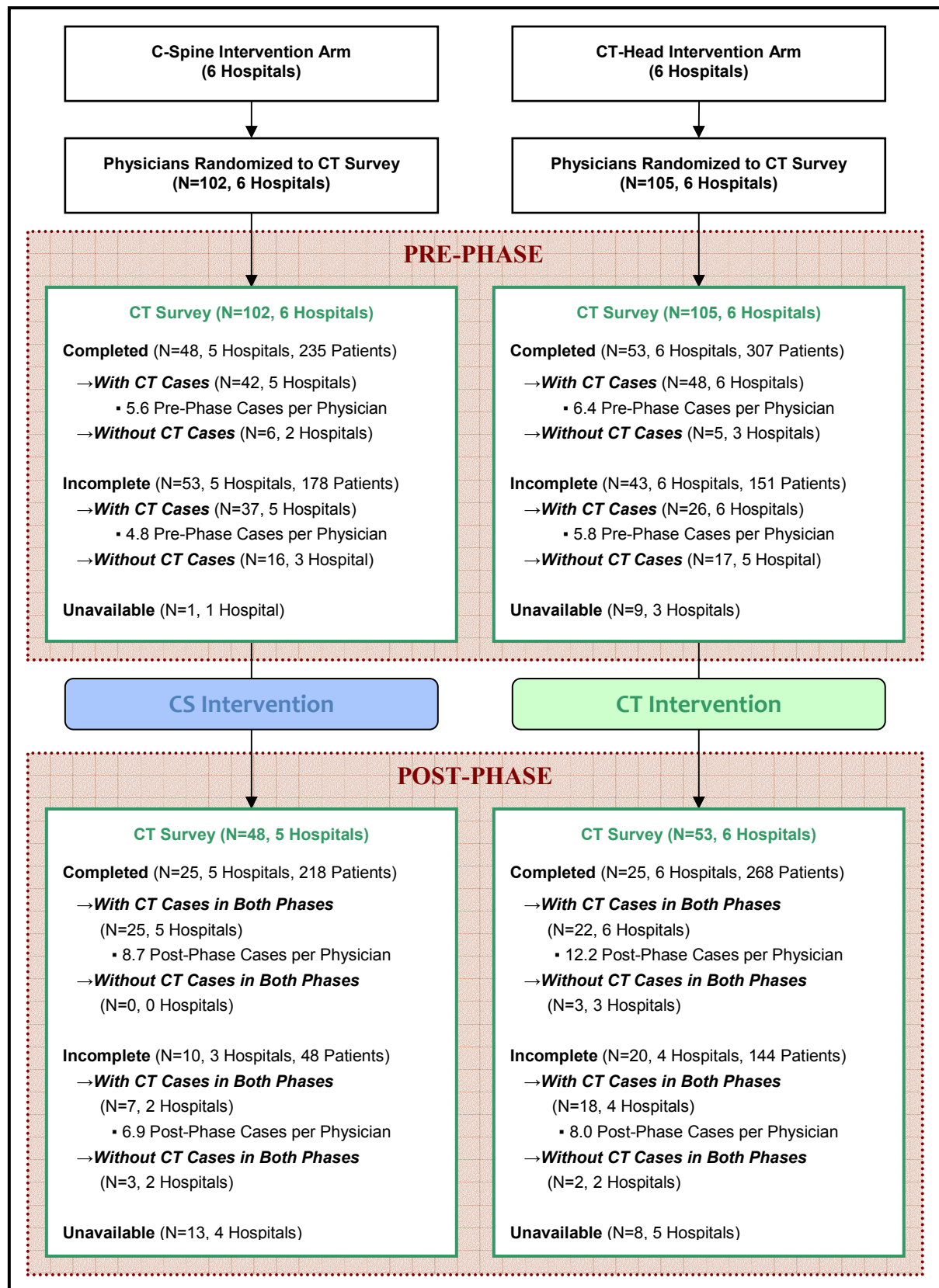


Figure 12 describes the distribution of CT patients among the physicians who were randomized to a CT survey. As with the CS study, TPB surveys were administered to physicians within the CT study deemed to be active at the participating hospitals but it was not assured that they would subsequently treat any eligible CT patients within either phase. 48 of the 53 physicians in the CT intervention group who completed a CT pre-phase survey treated eligible CT patients in the pre-phase, signifying that there was no behaviour data for 5 respondents with completed pre-phase surveys. 42 of the 48 physicians in the CT control group who completed a CT pre-phase survey treated eligible patients in the pre-phase, signifying that there was no behaviour data for 6 respondents with completed pre-phase surveys. On the other hand, several physicians who had not completed their surveys also did not have any behaviour data in the pre-phase and therefore would not have contributed to any analysis of the behaviour of interest even if they had completed a survey. 22 of the 25 physicians in the CT intervention group who completed a CT survey in both phases also treated eligible CT patients in both phases, signifying that 3 respondents with completed CT surveys in both phases did not treat patients in both phases. All 25 physicians in the CT intervention arm who completed a CT survey in both phases also treated eligible CT patients in both phases, signifying that there were no respondents that completed CT surveys in both phases and had not treated patients in both phases. As with the CS survey respondents, CT survey respondents may represent physicians who are either more active or regular at their hospitals.

Figure 12: Distribution of CT Patient Cases among Physicians Randomized to CT Surveys



ANALYSIS

This section will outline the analytical methodology used for examining the hypotheses of this study. A description of the modeling strategy used throughout this section is provided at the beginning, followed by the analytical plans for each individual objective.

Hierarchical Modeling Strategy

It was not reasonable to assume that data collected through the TPB surveys or patient level data collected through the implementation studies were independent measures. For data collected through the TPB surveys, it was plausible that the hospital within which a physician was located influenced the survey measures, resulting in correlations in responses from physicians at the same hospital. Linear mixed models allow us to account for the intraclass correlation in a regression model of interest by declaring clusters as random effects. Thus, linear mixed models were used in the analysis of various objectives within this project that was limited to the TPB surveys. For these models, Restricted Maximum Likelihood (REML) estimates and Kenward-Roger degrees of freedom methods were employed. For the patient level data collected through the implementation studies, it was necessary to use models that could adjust for multiple levels of correlated data and simultaneously allow for the prediction of radiography ordering, a dichotomous outcome. It would not be reasonable to assume that patients treated by the same physician or at the same hospital were independent.⁶⁴ Generalized linear mixed models are statistical models which allow for the modeling of correlated data when the outcome is not normally distributed, as in the case of dichotomous outcomes.^{65,66} Thus, generalized linear mixed models were used in

the analysis of various objectives within this project that used patient level data. For these models, the GLIMMIX procedure in SAS v.9.2 was used with the distribution of the response variable defined as binary and the link function between the predictors and outcome defined as logit.⁶⁷ The models were fitted using Residual Pseudo-Likelihood (RSPL) estimates and Kenward-Roger degree of freedom methods. Both the linear mixed models and generalized linear mixed models used throughout this project used the ‘nobound’ option, which allows for the estimation of negative variances. This was predicated on findings in the literature that constraining variance estimates to positive values lowers the Type I error rate and power in group-randomized trials.⁶⁷ These modeling parameters for mixed linear models and generalized linear mixed models set out here were used throughout the analysis for this project unless otherwise indicated.

Objective #1: Did the TPB surveys yield reliable and valid measures of the TPB constructs?

Since the TPB constructs are latent and not directly observable, initial work must be carried out to examine whether items in our survey measure the TPB constructs consistently, and measure the constructs we think they are measuring. Internal consistency, for example, assesses the consistency with which different survey items are correlated with each other, and therefore presumably measure the same construct. According to a systematic review of studies using social cognitive theories to explain the intention of health care professionals; studies with internally consistent measures of their psychological constructs predict a greater proportion of the variance in intention.⁵² Thus, obtaining internally consistent measures of each TPB construct is fundamental for making predictions of intention and behaviour; tasks that are necessary to evaluate the TPB model.

Validity refers to the degree to which measures actually assess the intended construct. Items may produce reliable measures yet not measure the construct they were intended to measure. If our measures are not valid representations of the TPB constructs, then any conclusions derived from them cannot be applied to the TPB model. Given that the methods of assessing the constructs are standardized, and has been applied to the behaviours of health care providers in many contexts, then it is reasonable to expect the TPB constructs as measured by the existing TPB methodology to be valid.⁴⁷ Nevertheless, we will still evaluate the construct validity of intention, since it is of central importance in the TPB model, acting as a linchpin between the other TPB constructs and the behaviour of interest. Evaluation of the overall TPB model is problematic if the measures of intention used are not valid. Since this project aims to assess the TPB model, it is necessary to ascertain that our measures of intention are in fact valid.

The following hypotheses will be evaluated to address Objective #1:

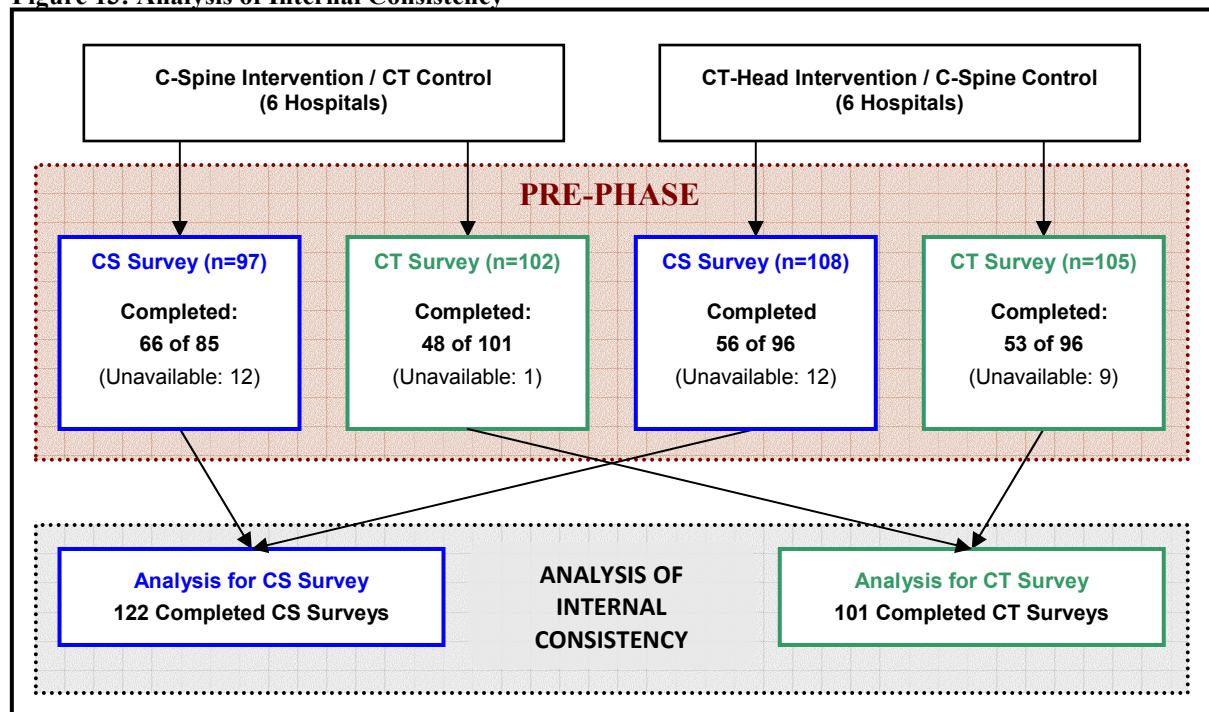
- I. TPB construct scores are internally consistent;
- II. The TPB construct score of Intention demonstrates validity with lower scores of Intention (to clinically clear without radiography) associated with more reported barriers to CDR use.

Analysis for Hypothesis I: Internal Consistency

Internal consistency was evaluated using Cronbach's alpha which assesses the correlation between items measuring a common construct.⁷¹ Due to the relatively small number of survey participants, this analysis was performed using only pre-phase survey data, thereby allowing us to group together the intervention and control groups of each TPB survey (Figure 13). The combining of the CS pre-phase survey's intervention and control groups resulted in a total of 122 respondents on which to evaluate the internal consistency of the CS survey's TPB constructs. The combining of the CT pre-phase survey's intervention and control groups resulted in a total of 101 respondents on which to evaluate the internal consistency of the CT survey's TPB constructs. Thus, we were provided with greater sample sizes by which to evaluate the internal consistency of each survey's TPB construct measures. A Cronbach's alpha was constructed for each pre-phase survey's set of attitude items, using all four relevant items. All attitude items had 7 point response scales of the same polarity, thereby allowing the Cronbach's alpha to be constructed without any altering of the responses. A Cronbach's alpha was constructed for each pre-phase survey's set of subjective norms items, using all three relevant items. All subjective norms items had 7 point response scales, but the second item (Table 1) had a scale of reverse polarity in comparison to the other two items, and therefore its responses had to be reversed before the Cronbach's alpha was constructed. A Cronbach's alpha was constructed for each pre-phase survey's set of

perceived behavioural control items, using all five relevant items. All perceived behavioural control items had 7 point response scales, but the first and fourth items (Table 1) had scales of reverse polarity in comparison to the other two items, and therefore their responses had to be reversed before the Cronbach's alpha was constructed. A Cronbach's alpha was constructed for each pre-phase survey's set of intention items, using all four relevant items. All intention items had scales of the same polarity but the first three items had 7 points scales, and the fourth item has a 6 point scale (Table 1). Thus, the fourth items' responses had to be reweighted to 7 point scales before the construction of the Cronbach's alpha. Items that were extreme outliers in comparison to other items of the same TPB construct were examined for possible inconsistencies. In accordance with the existing literature, Cronbach's alphas of 0.60 or higher were regarded as adequate measures of internal consistency.⁷¹

Figure 13: Analysis of Internal Consistency



Analysis for Hypothesis II: Validity

When there are no gold standards by which to evaluate the construct validity of TPB construct scores, construct validity can be evaluated through hypothesis testing.⁶³ For example, if each survey actually measures intention to clear patients without radiography, then lower scores of intention should correlate with more indications of barriers to use the respective clinical decision rule of each survey. We decided to use a mixed modeling approach to evaluate whether intention scores differed by whether physicians indicated potential barriers. Due to the relatively small number of survey participants, this analysis was performed using only pre-phase survey data, thereby allowing us to group together the intervention and control groups of each TPB survey as had been done in the analysis of internal consistency (Figure 13). Additionally, we pooled across the two types of surveys (CS, CT), providing a total of 223 physicians for this analysis. For the mixed model used in this analysis, the outcome of interest was intention score (continuous) and the random effects were the hospitals. The fixed effects were a dichotomous variable indicating whether potential barriers were indicated, a dichotomous variable indicating the survey (CS, CT), and the interaction between these two dichotomous variables. The interaction term between the indication of potential barriers and the type of survey was included to investigate whether the results were different for the two clinical contexts. The difference between least-square means estimates of physicians who indicated potential barriers and physicians who did not indicate potential barriers was tested for significance in each survey using CONTRAST statements in SAS.

Objective #2: Do TPB constructs predict intention to engage in the target behaviour (clinical clearance without radiography) in this clinical context?

Although TPB has been shown to explain a large proportion of the variance for various behaviours in numerous contexts, including both patient and physician behaviours, it is important to evaluate the extent to which TPB constructs specifically predict intention to clinically clear without radiography in the contexts of the CS and CT Rules.⁵² Constructs not included in the TPB could mitigate its relevance in this context. For example, if intention to clear patients without radiography is primarily dependent on the level of regret a physician associates with missing a significant clinical outcome, then TPB constructs may have little or no effect in predicting intention since regret is not included in the main theory. Some studies have shown regret to add to the predictive utility of TPB, which was measured in the surveys but will not be considered for this research project.⁷²⁻⁷⁴ In addition, not all of the TPB constructs may be relevant for this clinical context. For example, if ED physicians are largely unaware of the opinions of their colleagues because they work largely independent of one another, subjective norms may not be an important predictor of intention to clear patients without radiography. The TPB model's proposed relationships between the predictors of intention (attitude, subjective norms, and perceived behavioural control) and intention itself will therefore be evaluated for each survey to better understand the relevance of TPB in these contexts.

The following hypotheses will be evaluated to address Objective #2:

- I. Attitudes that more positively value clinical clearance are associated with higher Intention to clinically clear
- II. Subjective Norms that perceive people of importance to more positively value clinical clearance are associated with higher Intention to clinically clear

III. Greater Perceived Behavioural Control is associated with higher Intention to clinically clear

Analysis for Objective 2

A mixed modeling approach was chosen to assess the association between the TPB constructs (attitude, subjective norms, and perceived behavioural control) and intention to clinically clear patients without radiography for each of the two clinical contexts. This analysis was performed using only pre-phase data, thereby allowing us to group together intervention and control groups for each survey as had been done in the analysis of internal consistency (Figure 13). Hospitals were declared as random effects for each model involved in the analysis of this objective to account for intracluster correlations of survey responses within hospitals. The outcome of interest for each model was intention to clinically clear and the fixed effects were the TPB constructs (attitude, subjective norms, perceived behavioural control). A multivariable mixed model was therefore fitted for each context to evaluate the associations between the TPB constructs and intention to clinically clear without radiography. To summarize the predictive ability of the model, we calculated the percentage of the variation in intention scores explained by the model, using an R^2 -like measure proposed for the analysis of mixed models.⁷⁵

Objective #3: Can TPB constructs predict actual clinical clearance (as opposed to intention to clinically clear) in this clinical context?

Although TPB posits that intention to perform a behaviour is the primary determinant of the behaviour itself, this relationship is never perfect. Individuals often fail to perform behaviours which they had every intention to complete, producing an intention-behaviour gap.⁷⁶ One explanation is that behaviours are not always under complete volition of individuals. TPB accounts for this by including perceived behavioural control as a moderator of the relationship between intention and behaviour, thereby acting as a proxy for actual control over the behaviour. The intention-behaviour gap, however, persists even when taking into consideration actual control over the behaviour.⁷⁷ The behaviour may therefore be functioning through additional constructs not contained within the TPB model or may even be functioning outside the TPB framework entirely. The extent to which the relationships between the TPB constructs (intention, perceived behavioural control) and behaviour apply in this context will therefore be evaluated.

The following hypotheses will be evaluated to address Objective #3:

- I. Higher Intention to clinically clear is associated with a greater likelihood of performing clinical clearance
- II. Greater Perceived Behavioural Control is associated with a greater likelihood of performing clinical clearance

Analysis for Objective 3:

Generalized linear mixed models were fitted to assess whether the TPB constructs were associated with clinical clearance without radiography in the context of the CS and CT rules. This analysis was performed using only pre-phase data, thereby allowing us to group together intervention and control groups for each survey (CS: Figure 14; CT: Figure 15). The datasets were prepared for this analysis by merging each physician's TPB pre-phase construct scores to their respective patient cases within each pre-phase of the implementation studies. A model was constructed for each context, with clinical clearance without radiography as the dichotomous outcome of interest, the TPB construct scores of intention and perceived behavioural control entered as the fixed effects of interest, and physician and hospital identifiers entered as random effects to account for clustering of patients by physician and hospital. As a result, these models were limited to patient cases that were treated by physicians who had completed a corresponding TPB pre-phase survey. It was plausible that patient severity could have biased the results of these models since the implementation studies did not include any type of control over the types of patients treated at each hospital, or by each physician. Some hospitals may have had more severe patients than others, or some physicians may have had more severe patients than others; thereby potentially biasing any associations between TPB construct scores and radiography rates. Patients who arrived by ambulance or who were subsequently admitted to the hospital may tend to involve more severe injuries than those who arrived to the hospital by their own means or who were not admitted. These two factors were included in the models as additional fixed effects to potentially control for patient severity. We were therefore provided with a model for each clinical context by which to evaluate if the TPB constructs were actually associated with the behaviour of interest.

Figure 14: Analysis of Association between TPB constructs and CS Clinical Clearance

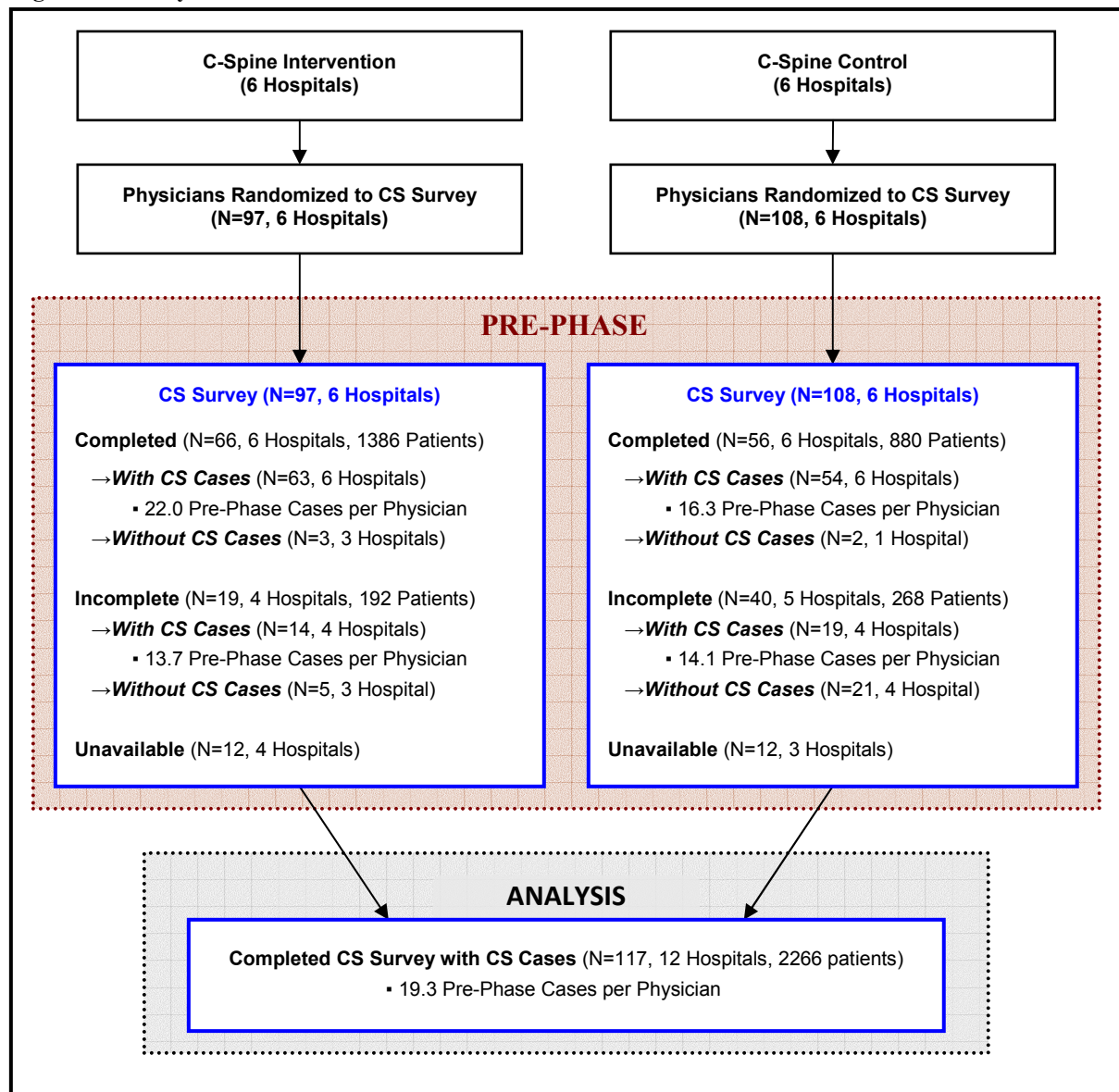
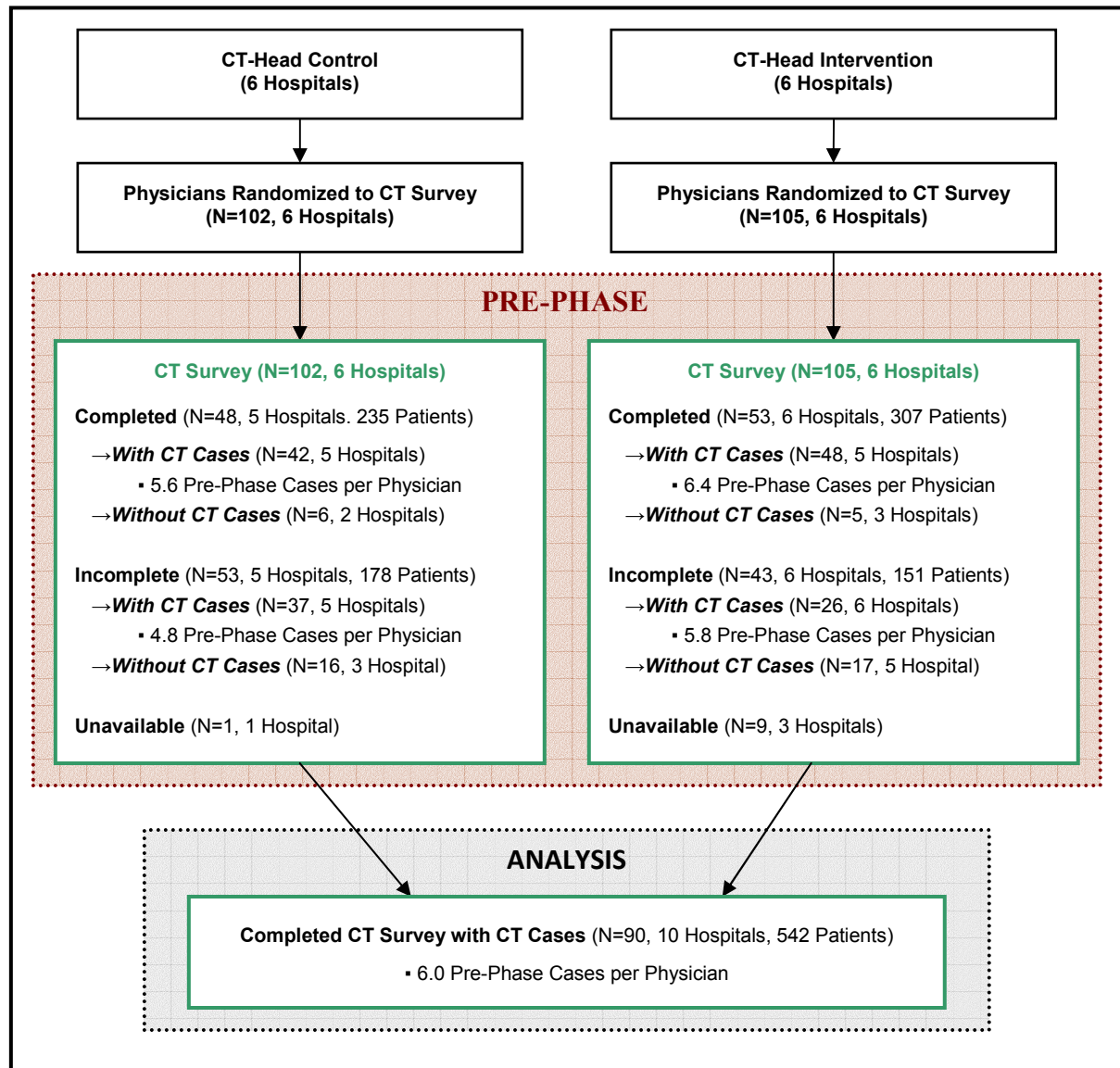


Figure 15: Analysis of Association between TPB constructs and CT Clinical Clearance



Objective #4: Did the intervention result in any changes of the TPB constructs?

If, as the TPB predicts, TPB constructs are the primary determinants of behaviour, then the success or failure of any behavioural intervention will principally depend on its ability to change those constructs. The theory predicts that a successful behavioural intervention should change some or all of the TPB constructs. By examining longitudinal changes in all the TPB constructs (attitude, subjective norms, perceived behavioural control, and intention) and not simply the constructs posited to be the most proximal determinants of behaviour (intention, perceived behavioural control), we can evaluate which TPB pathways a successful intervention targeted. Behaviour change that cannot be explained through a TPB pathway would suggest that the intervention acted through constructs not contained within TPB. In such circumstances, TPB may not be an appropriate theory by which to examine behaviour change, or may require the inclusion of additional constructs if it is to be useful. We therefore examined whether the interventions employed in the implementation studies actually changed the TPB constructs. Given the differing results of the implementation studies, the following hypotheses will be evaluated when assessing whether any changes in the TPB constructs occurred:

- I. The intervention that successfully reduced CS radiography also significantly increased each of the CS TPB constructs;
- II. The intervention that did not successfully reduce CT radiography also did not significantly increase any of the CT TPB constructs;

Analysis for Objective 4

A model was constructed for each TPB construct (intention, attitude, subjective norms, and perceived behavioural control) in each survey (CS, CT) to evaluate whether any had changed due to the interventions employed in the implementation studies. This meant the construction of four models per survey, for a total of eight separate models. This analysis was restricted to TPB survey data from physicians who had completed a survey in each phase (CS: Figure 16; CT: Figure 17). A mixed modeling approach was chosen to adjust for potential correlations among the responses of physicians located at the same hospitals. For each model, the post-phase TPB construct score served as the outcome of interest, the pre-phase score and the group (intervention/control) variable served as fixed effects, and hospitals was declared as a random effect. By including pre-phase scores as a predictor, one adjusts for the possibility that intervention and control groups had different baseline values of the TPB construct score in question. Since the sizes of the intervention and control groups were small, it was plausible that the models would not converge. In the event that this occurred, variances were constrained to positive values, thereby simplifying the model and increasing the chances of convergence.⁶⁷ Thus, a mixed model was constructed for each TPB construct on each survey, thereby allowing us to evaluate whether the TPB constructs changed as hypothesized.

Figure 16: Analysis of TPB Construct Changes in CS Study

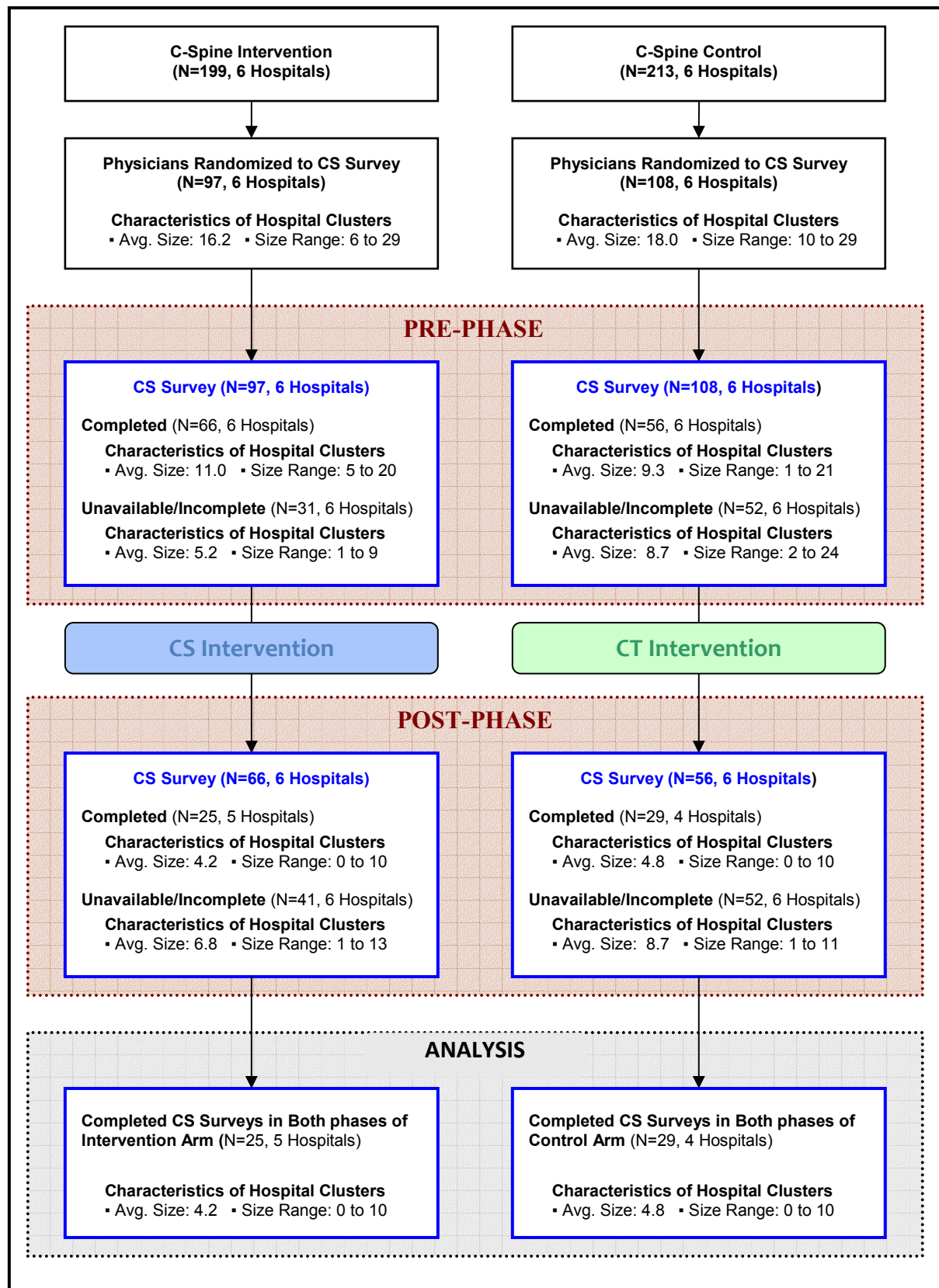
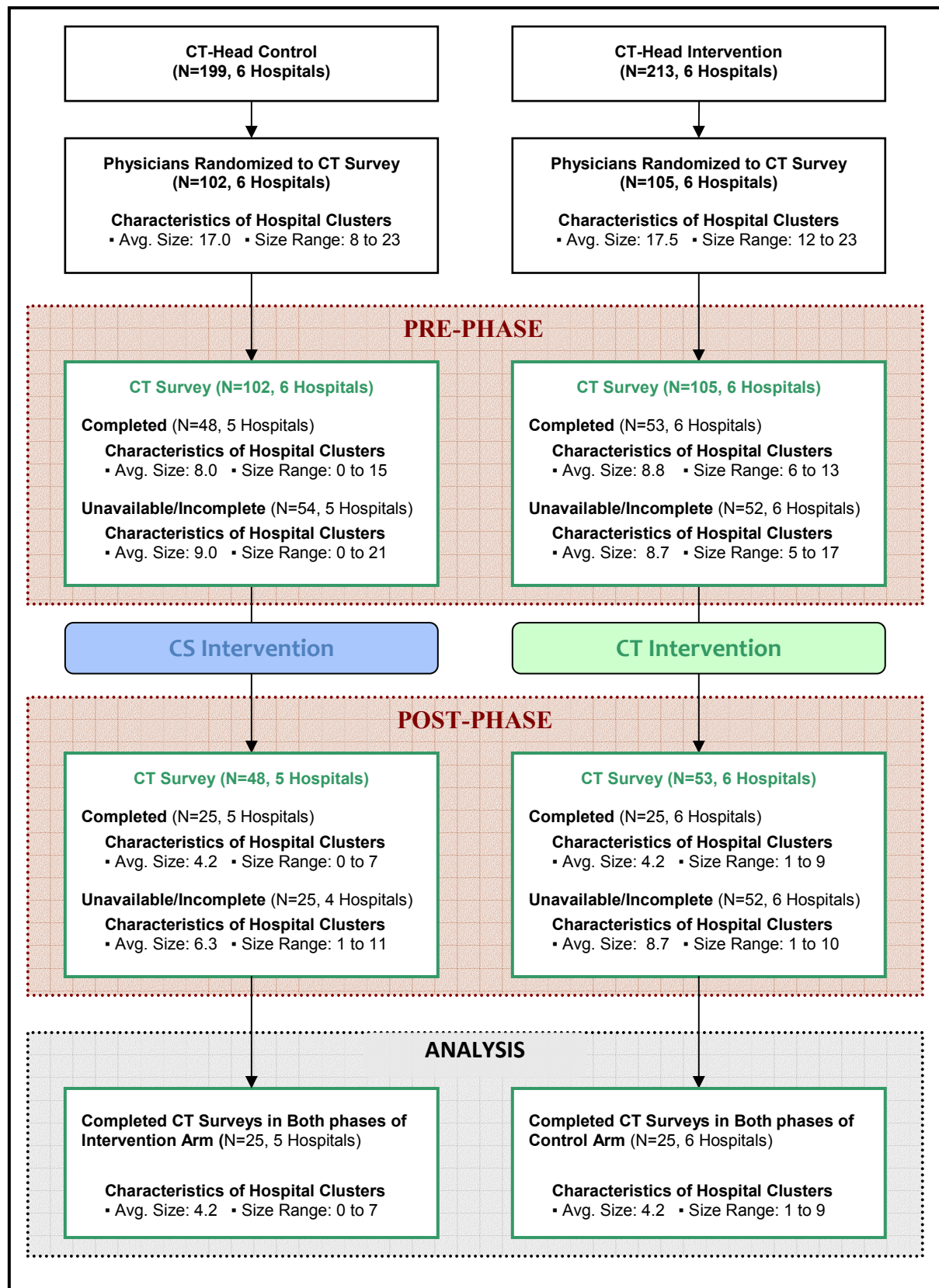


Figure 17: Analysis of TPB Construct Changes in CT Study



Objective #5: Do changes in TPB constructs predict changes in the rate of clinical clearance?

If behaviour change is to be explained by TPB, then it must be demonstrated that behaviour change is associated with changes in the TPB constructs. TPB contends that the primary determinant of an individual's behaviour is their intention to perform that behaviour, and that this relationship is mediated by perceived behavioural control which acts as a proxy for actual control in performing the behaviour. Many studies simply examine the association between these TPB constructs and the behaviour of interest at one point in time.

Examination of whether changes in the behaviour are associated with changes in the TPB constructs, however, can provide additional insight into the utility of a theory. Behaviour change that occurs without corresponding changes in the constructs would suggest that any changes in behaviour are occurring outside the TPB framework. Changes in the TPB constructs that occur without corresponding changes in the behaviour of interest would suggest that manipulation of the TPB constructs may not be sufficient to change behaviour.

We will therefore evaluate whether changes in clinical clearance can be explained by changes in the TPB constructs through the following hypotheses:

- I. Changes in Intention and Perceived Behavioural Control predict Changes in CS clinical clearance
- II. Changes in Intention and Perceived Behavioural Control predict changes in CT clinical clearance

Analysis for Objective 5

A generalized linear mixed model was constructed for each clinical context to evaluate whether changes in the TPB constructs predicted changes in clinical clearance (CS: Figure 19; CT: Figure 20). Each of these models was constructed with clinical clearance without radiography entered as the bivariable outcome of interest, and hospital and physician indicators entered as random effects to adjust for potential clustering of patients by hospital or physician. Arrival by ambulance and hospital admittance were entered as fixed effects to adjust for patient severity, as had been done in objective #3. The TPB constructs (intention, perceived behavioural control) of interest were entered as time-varying fixed effects. A three-way interaction was entered for each TPB construct (intention, perceived behavioural control) which consisted of the TPB construct, the group (intervention/control) and phase (pre/post). All two-way interactions and main effects of these variables were also entered as is habitually done in the analysis of interactions. In this manner, we could investigate whether there were any differences in the associations between the TPB constructs and clinical clearance across phases and groups. Significant interaction effects were explored using CONTRAST statements in SAS. Figure 18 presents the fixed effects part of the model.

Figure 18: Fixed Effects terms in the Model

$$\begin{aligned}\text{logit(Clinical Clearance)} = & \beta_0 + \beta_1 \text{Intention} + \beta_2 \text{PBC} + \beta_3 \text{Group} + \beta_4 \text{Phase} \\ & + \beta_5 \text{Ambulance} + \beta_6 \text{Admitted} + \beta_7 \text{Group*Phase} \\ & + \beta_8 \text{Intention*Group} + \beta_9 \text{Intention*Phase} + \beta_{10} \text{Intention*Group*Phase} \\ & + \beta_{11} \text{PBC*Group} + \beta_{12} \text{PBC*Phase} + \beta_{13} \text{PBC*Group*Phase}\end{aligned}$$

Figure 19: TPB-Based Process Evaluation of CS Implementation Study

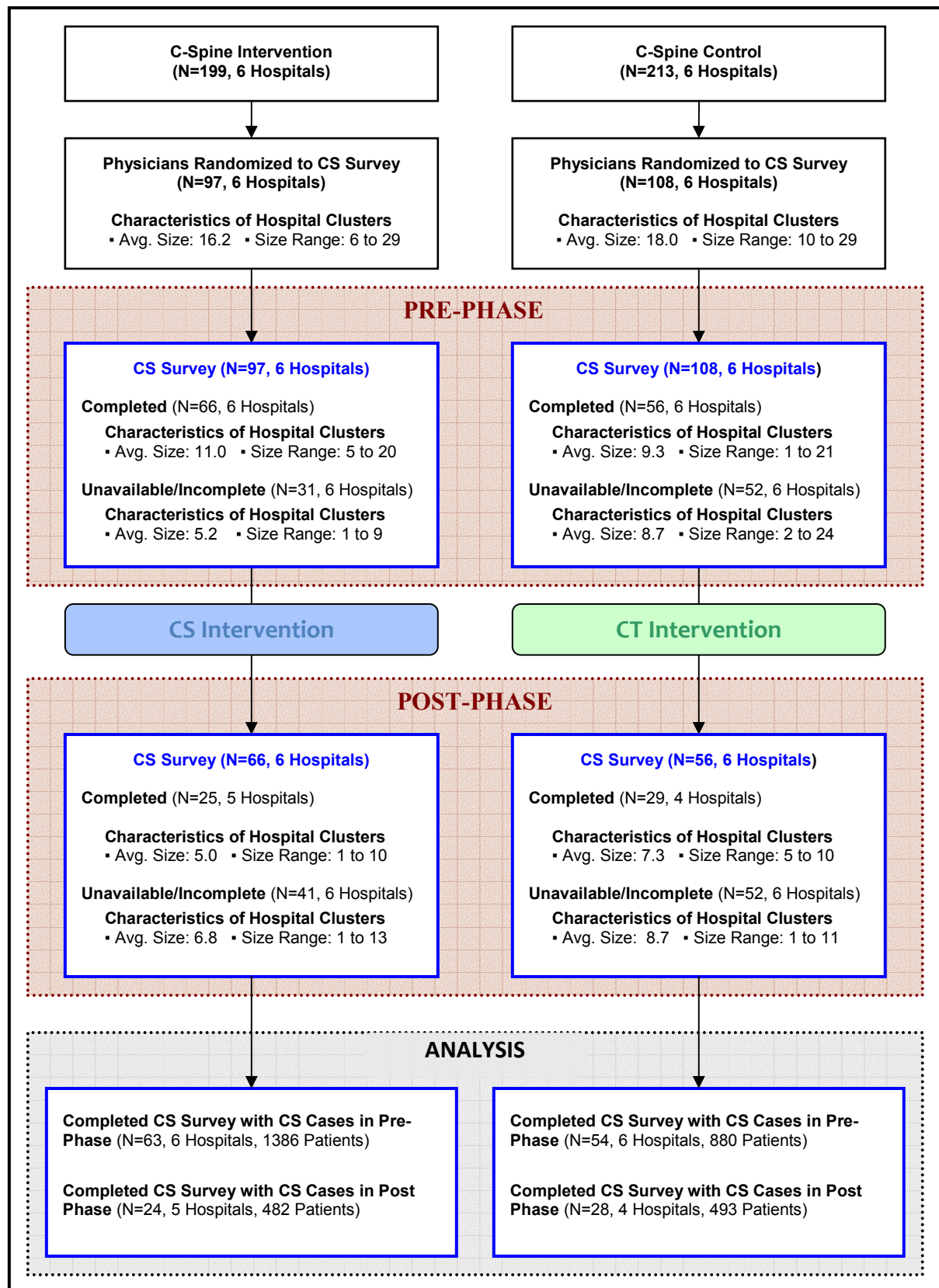
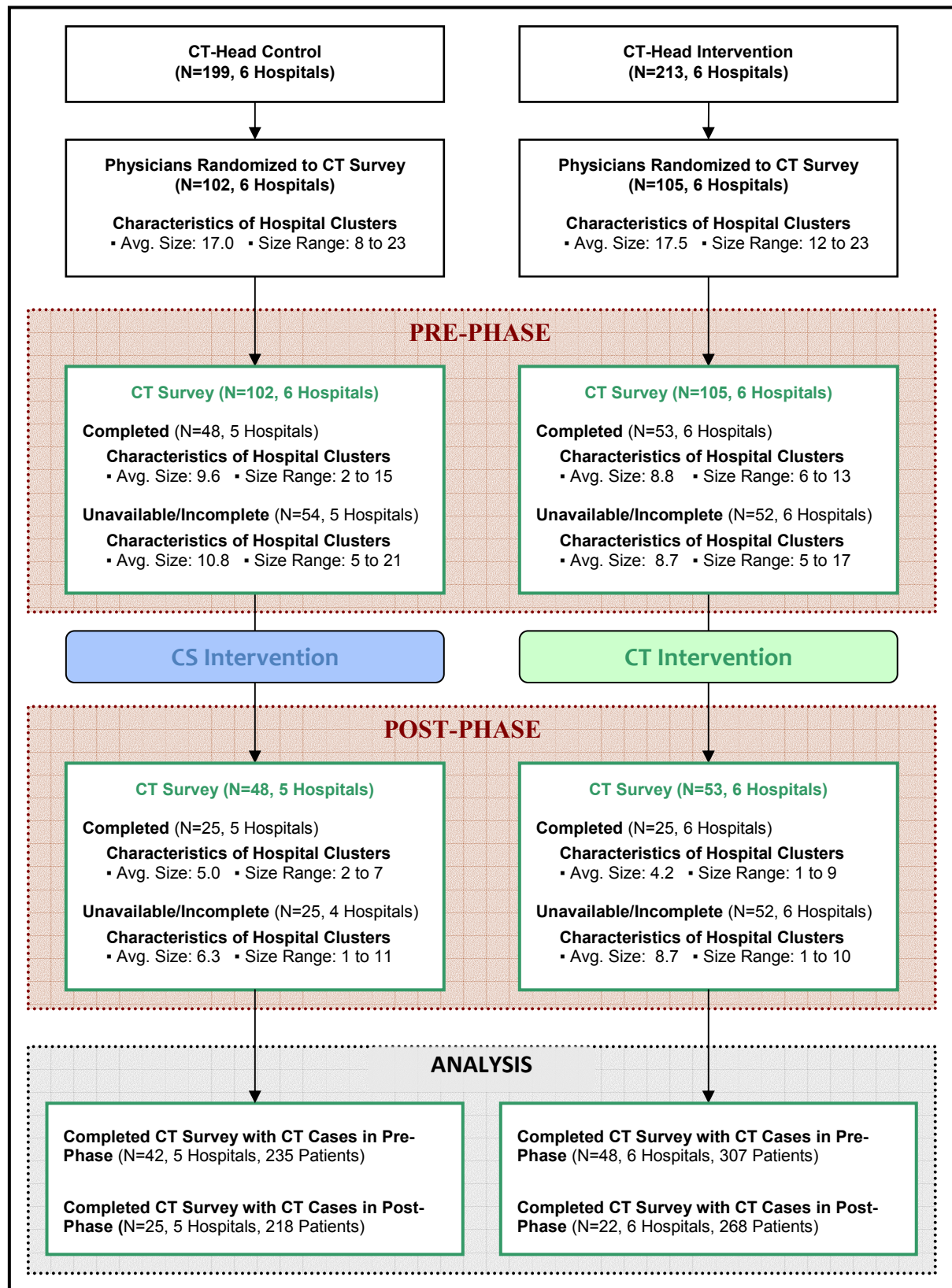


Figure 20: TPB-Based Process Evaluation of CT Implementation Study



RESULTS

Objective #1: Did the TPB surveys yield reliable and valid measures of the TPB constructs?

Hypothesis I: Internal Consistency

Table 5 and 6 describe the Cronbach's alphas that were computed for the CS and CT surveys to examine internal consistency of the TPB construct measures. The Cronbach's alpha for attitude was 0.91 for the CS survey and 0.98 for the CT survey, demonstrating adequate internal consistency in both cases. 121 of the 122 CS survey respondents and 97 of the 101 CT survey respondents had completed all 4 attitude items on their respective survey. The mean responses to these items ranged from 6.26 to 6.53 on the CS Survey and from 5.03 to 5.35 on the CT survey. Given that the response scales for each of these items had a maximum score of 7, it would appear that there was a ceiling effect where the majority of measures were at or near the maximum. This ceiling effect also appears to be more pronounced in the CS survey than in the CT survey. A ceiling effect reduces variability, leading to underestimates of means, standard deviations, and reliability.⁷⁸ In the case of Cronbach's alpha, a ceiling effect increases this measure and therefore inflates the internal consistency of our measures. The interpretation of subsequent analysis involving these measures of attitude had to take into account the ramifications of this ceiling effect.

The Cronbach's alpha for subjective norms was 0.26 for the CS survey and 0.55 for the CT survey, demonstrating inadequate internal reliability in both cases. 115 of the 122 CS survey respondents and 96 of the 101 CT survey respondents had completed all 3 subjective norms items for their respective survey. The mean responses to these items on 7 point scales ranged from 3.52 to 6.12 on the CS survey and 3.54 to 5.35 on the CT survey. The poor

level of internal reliability was largely due to the inclusion of the second subjective norm item which was poorly correlated with the first and third subjective norm items. In the CS survey, the second item was negatively correlated with the first ($r = -0.17$) and third item ($r = -0.21$). In the CT survey, the second item demonstrated poor correlation with the first ($r = 0.14$) and third item ($r = 0.05$). The second item on each survey was different from the other two items in that the polarity of its response scale was reversed in reference to the response scales of the other two items (Table 1). Given that this second subjective norms item was the first item on both surveys where the response scale was reversed, it is plausible that many survey participants answered the item unaware that the response scale no longer had the same polarity as previous items. The second subjective norms item was removed from the set of subjective norms items for each survey, resulting in sets of only two items. The mean responses to these two remaining items ranged from 5.68 to 6.12 on the CS survey and 4.74 to 5.35 on the CT survey. Cronbach's alpha was no longer an appropriate method of evaluating the internal consistency of the remaining items since it requires a set of at least three items.⁷¹ Instead, a Pearson correlation was utilized which demonstrated adequate internal consistency of the two remaining items with a value of 0.54 in the CS survey and 0.75 in the CT survey.⁷⁹ A ceiling effect was apparent in the measures of the CS survey, which had to be taken into consideration in the interpretation of subsequent analysis.

The Cronbach's alpha for perceived behavioural control was 0.72 for the CS survey and 0.71 for the CT survey, demonstrating adequate internal reliability in both cases. 118 of the 122 CS survey respondents and 98 of the 101 CT survey respondents had completed all 5 perceived behavioural control items on their respective survey. The mean responses to these items on 7 point scales ranged from 4.11 to 5.91 on the CS Survey and from 4.02 to 5.55 on the CT survey. There was no need to drop any items or any plausible ceiling effect that

would require special consideration in the interpretation of subsequent analysis involving these measures of perceived behavioural control.

The Cronbach's alpha for intention was 0.92 for the CS survey and 0.98 for the CT survey, demonstrating adequate internal reliability in both cases. 120 of the 122 CS survey respondents and 97 of the 101 CT survey respondents had completed all 3 intention items on their respective survey. The mean responses to these items on 7 point scales ranged from 5.96 to 6.53 on the CS Survey and from 5.03 to 5.35 on the CT survey. As in the case of attitude measures, a ceiling effect was demonstrated in intention measures that was more pronounced in the CS survey than in the CT survey. The interpretation of subsequent analysis involving these measures of intention had to take into account the ramifications of this ceiling effect.

Overall, the methodology by which the two TPB-based surveys were constructed resulted in internally consistent measures of the TPB constructs. Cronbach's alphas ranged from 0.71 to 0.98 for intention, attitude, and perceived behavioural control across both clinical contexts. Pearson correlations ranged from 0.54 to 0.75 for subjective norms across both clinical contexts. These findings are consistent with the literature and our hypothesis.^{71;79} Based on these final sets of internally consistent items, a score for each TPB construct (attitude, subjective norms, perceived behavioural control, and intention) on each survey was constructed by realigning the responses of its items to the same polarity and then taking the mean of its items to produce a score out of a maximum of 7. These scores were utilized in the evaluation of the subsequent objectives.

TABLE 5: Internal Consistency of TPB Constructs for C-Spine Survey

TPB Construct	Cronbach's Alpha	Survey Item Descriptions with <i>Ends of Response Scale</i>	Mean (S.D.)	Cronbach's Alpha if Item Removed
Attitude (n=121)	0.91	1. Clinically Clearing the C-Spine is: <i>Bad Practice / Good Practice</i>	6.53 (0.75)	0.92
		2. Clinically Clearing the C-Spine is: <i>Harmful / Beneficial</i>	6.26 (1.19)	0.87
		3. Clinical Clearing the C-Spine is: <i>Negative / Positive</i>	6.40 (0.94)	0.86
		4. Clinical Clearing the C-Spine is the: <i>wrong thing to do / right thing to do</i>	6.28 (1.21)	0.85
Subjective Norms (n=115)	0.26	1. Most of my Professional Colleagues will Clinically Clear the C-Spine: <i>Definitely No / Definitely Yes</i>	5.68 (1.00)	-0.17
		2. People Important to Me think I should Clinically Clear the C-Spine: <i>Definitely Should Not/Definitely Should</i>	3.52 (2.05)	0.69
		3. The Canadian Association of Emergency Physicians would: <i>Definitely Disapprove/ Definitely Approve</i>	6.12 (0.96)	-0.21
Perceived Behavioural Control (n=118)	0.72	1. Clinically Clearing the C-Spine is: <i>Difficult / Easy</i>	4.28 (1.62)	0.71
		2. Likelihood that you will be able Clinically Clear the C-Spine is: <i>Very Unlikely / Very Likely</i>	5.69 (1.00)	0.58
		3. I am confident that I could Clinically Clear the C-Spine if I wanted to: <i>Strongly Disagree / Strongly Agree</i>	5.91 (1.22)	0.56
		4. Factors outside my control prevent me from Clinically Clearing the C-Spine: <i>Strongly Agree / Strongly Disagree</i>	4.11 (2.03)	0.65
		5. How much control do you have over Clinically Clearing the C-Spine: <i>No Control / Complete Control</i>	5.72 (1.12)	0.52
Intention (n=120)	0.92	1. I intend to Clinically Clear the C-Spine: <i>Definitely Do Not / Definitely Do</i>	6.54 (0.71)	0.88
		2. I want to Clinically Clear the C-Spine: <i>Definitely Do Not / Definitely Do</i>	6.58 (0.72)	0.88
		3. I plan to Clinically Clear the C-Spine: <i>Definitely Do Not / Definitely Do</i>	6.52 (0.79)	0.88
		4. My Desire to Clinically Clear the C-Spine can be described as: <i>No Desire / Very Strong</i>	5.96 (0.77)	0.93

TABLE 6: Internal Consistency of TPB Constructs for CT-Head Survey

TPB Construct	Cronbach's Alpha	Survey Item Descriptions with <i>Ends of Response Scale</i>	Mean (S.D.)	Cronbach's Alpha if Item Removed
Attitude (n=97)	0.98	1. Managing Patients without CT is: <i>Bad Practice / Good Practice</i>	5.35 (1.50)	0.98
		2. Managing Patients without CT is: <i>Harmful / Beneficial</i>	5.03 (1.62)	0.98
		3. Managing Patients without CT is: <i>Negative / Positive</i>	5.19 (1.54)	0.96
		4. Managing Patients without CT is the: <i>wrong thing to do / right thing to do</i>	5.26 (1.52)	0.96
Subjective Norms (n=96)	0.55	1. Most of my Professional Colleagues will Manage Patients without CT: <i>Definitely No / Definitely Yes</i>	4.74 (1.54)	0.14
		2. People Important to Me think I should Manage Patients without CT: <i>Definitely Should Not/Definitely Should</i>	3.54 (1.66)	0.86
		3. The Canadian Association of Emergency Physicians would: <i>Definitely Disapprove/ Definitely Approve</i>	5.35 (1.39)	0.05
Perceived Behavioural Control (n=98)	0.71	1. Managing Patients without CT is: <i>Difficult / Easy</i>	4.02 (1.64)	0.66
		2. Likelihood that you will be able Manage Patients without CT is: <i>Very Unlikely / Very Likely</i>	5.39 (1.45)	0.56
		3. I am confident that I could Manage Patients without CT if I wanted to: <i>Strongly Disagree / Strongly Agree</i>	5.54 (1.31)	0.60
		4. Factors outside my control prevent me from Managing Patients without CT: <i>Strongly Agree / Strongly Disagree</i>	4.24 (1.83)	0.73
		5. How much control do you have over Managing Patients without CT: <i>No Control / Complete Control</i>	5.55 (1.18)	0.67
Intention (n=97)	0.98	1. I intend to Manage Patients without CT: <i>Definitely Do Not / Definitely Do</i>	5.33 (1.66)	0.96
		2. I want to Manage Patients without CT: <i>Definitely Do Not / Definitely Do</i>	5.39 (1.67)	0.97
		3. I plan to Manage Patients without CT: <i>Definitely Do Not / Definitely Do</i>	5.36 (1.65)	0.96
		4. My Desire to Manage Patients without CT can be described as: <i>No Desire / Very Strong</i>	5.12 (1.42)	0.98

Hypothesis II: Validity check

Validity of the TPB construct scores was examined through a test of the hypothesis that physicians who did not indicate any barriers in clearing patients without radiography would have higher intention scores. Using pre-phase responses, physicians were divided into two groups based on whether they listed or did not list any barriers. A mixed model was utilized to examine whether there was a difference in pre-phase intention scores between the two groups (Table 7, Table 8). The significant interaction between the indication of potential barriers and the type of survey demonstrated a significant difference between the two clinical contexts examined. In the CT survey, physicians who indicated potential barriers had significantly lower intention scores (mean=4.83) than physicians who did not indicate any barriers (mean=5.90). In the CS survey, physicians who indicated potential indicators had lower intention scores (mean=6.28) than physicians who did not indicate any barriers (mean=6.50), but this difference was not statistically significant. Given that the difference between the groups in the CS context was in the hypothesized direction, the more pronounced ceiling effect within the CS intention measures may have prevented the detection of a significant difference by limiting the amount of variation. In general, these results are consistent with the hypothesis that intention is correlated with the indication of potential barriers, and provide some evidence for the validity of the measures.

TABLE 7: Mixed Linear Model Predicting Intention to Clinically Clear without Radiography by Indication of Barriers (N=119; CS Surveys=66; CT Surveys=53; ICC=0.03)

Variables	Parameter Estimate (95% CI)	p-value
Intercept	6.50 (6.16, 6.84)	<0.01
Indicated Barriers (No=0; Yes=1)	-0.23 (-0.74, 0.28)	0.38
Survey (CS=0; CT=1)	-0.60 (-1.13, -0.07)	0.03
Indicated Barriers * Survey	-0.85 (-1.61, -0.09)	0.03

TABLE 8: Comparison of Least-square means of Intention for Levels of Interaction in Model Predicting Intention to Clinically Clear without Radiography

Clinical Contexts	Mean Intention (95% CI) by Indication of Barriers		p-value
	No	Yes	
CS (N=66)	6.50 (6.16, 6.84)	6.28 (5.90, 6.65)	0.3823
CT (N=53)	5.90 (5.49, 6.32)	4.83 (4.48, 5.18)	0.0003

Objective #2: Do TPB constructs predict intention to engage in the target behaviour (clinical clearance without radiography) in this clinical context?

The results of the mixed models to evaluate the TPB proposed relationships between the TPB constructs (attitude, subjective norms, and perceived behavioural control) and intention to clinically clear without radiography are presented in Table 9. The model for the CS context demonstrated attitude and subjective norms scores to be significant predictors of intention scores. This model predicted an intention score increase of 0.398 (95% CI: 0.292, 0.504) for every unit increase in attitude scores, while predicting an intention score increase of 0.263 (95% CI: 0.151, 0.376) for every unit increase in subjective norms' scores. These results were in accordance with our first two hypotheses that higher levels of attitude and subjective norms were associated with higher levels of intention to clear patients without radiography. Perceived behavioural control was not a significant predictor of intention ($p=0.35$). This result was inconsistent with our third hypothesis, that greater levels of perceived behavioural control were associated with higher levels of intention. Our model for the CS context explained 74% of the variance in intention scores.

In the model for the CT context, attitude and subjective norms scores were also significant predictors of intention scores (Table 9). This model predicted an intention score increase of 0.303 (95% CI: 0.160, 0.445) for every unit increase in attitude scores, while predicting an intention score increase of 0.728 (95% CI: 0.571, 0.884) for every unit increase in subjective norms scores. Like the CS context, the results for the CT context were also in accordance with our first two hypotheses that higher levels of attitude and subjective norms were associated with higher levels of intention to clear patients without radiography. Perceived behavioural control was not a significant predictor of intention ($p=0.27$). Like the

CS context, this result for the CT context was inconsistent with our third hypothesis, that greater levels of perceived behavioural control were associated with higher levels of intention. The model for the CT context explained 89% of the variance according to the same proposed estimate that was used in evaluating the CS context.

In general, the TPB model's proposed relationships between the predictors of intention and the TPB constructs functioned across both contexts in a similar manner. Intention was associated with attitude and subjective norms, but not perceived behavioural control in each context. Although intention was associated with the same TPB constructs in both contexts, it is important to note that the contribution of these constructs to the prediction of intention differed between contexts. A unit increase in attitude scores predicted a greater increase in the intention scores of CS (0.398) in comparison to CT (0.303). In contrast, a unit increase in subjective norms scores predicted an increase in the intention scores of the CT (0.728) which was more than two times greater than the predicted increase in the CS (0.263). Thus, intention to clear patients without radiography appears to be influenced more by attitude in the context of CS, while significantly more by subjective norms in the context of CT.

TABLE 9: Mixed Linear Models Predicting Intention to Clinically Clear without Radiography

Survey	C-Spine (N=122, ICC=0.02, R ² =0.74)		CT-Head (N=101, ICC=0.01, R ² =0.89)	
Variables	Parameter Estimate (95% CI)	P-value	Parameter Estimate (95% CI)	P-value
Intercept	2.617 (1.765, 3.469)	<0.001	-0.655 (-0.830, 0.520)	0.271
Attitude	0.398 (0.292, 0.504)	<0.001	0.303 (0.160, 0.445)	<0.001
Subjective Norms	0.263 (0.151, 0.376)	<0.001	0.728 (0.571, 0.884)	<0.001
Perceived Behavioural Control	-0.066 (-0.206, 0.074)	0.354	0.148 (-0.118, 0.413)	0.273

Objective #3: Can TPB constructs predict the actual target behaviour (clinical clearance without radiography) in this clinical context?

The results of the generalized linear mixed model to evaluate the relationships between the TPB constructs (intention, perceived behavioural control) and clinical clearance for the CS context are presented in Table 10. This model demonstrated that intention was a significant predictor of clinical clearance of radiography (OR=1.79). For every unit increase in intention scores, the odds of clinical clearance without radiography increased by 79%. This was consistent with our first hypothesis, that higher levels of intention to clear patients without radiography were associated with higher rates of clinical clearance without radiography. Perceived behavioural control was a marginally significant predictor of clinical clearance without radiography (OR=0.79; $p=0.08$). For every unit increase in perceived behavioural control, the odds of clinical clearance without radiography decreased by 21%. This was inconsistent with our second hypothesis, that greater levels of perceived behavioural control were associated with higher rates of clinical clearance without radiography. This counterintuitive association was likely a product of our model rather than a genuine representation of the relation between perceived behavioural control and clinical clearance. In the absence of random effects, the direction of this relation was reversed and not significant (OR=1.09; $p=0.28$), while the associations between the other predictors and clinical clearance were practically unchanged. This suggested that perceived behavioural control was correlated with the error residuals of the model; and therefore any association derived from its inclusion in the random effects model was not valid. The additional parameters that had been included to adjust for patient severity, arrival by ambulance (OR=0.24) and hospital admittance (OR=0.18) were also significant predictors of clinical clearance. Patients who arrived by ambulance had 76% decreased odds of clinical clearance without

radiography compared to patients who arrived by their own means. Patients who were admitted to the hospital had decreased odds of 82% of clearance without radiography compared to patients that were not admitted. These factors therefore did function as indicators of patient severity as had been intended. For the CS context, intention functioned as hypothesized, but perceived behavioural control was not relevant.

A generalized mixed linear model was also constructed to evaluate the relationships between the TPB constructs and clinical clearance for the CT context (Table 10). In this model, neither of the TPB constructs (intention, perceived behavioural control) were significant predictors of clinical clearance without radiography. The additional parameters that had been included to adjust for patient severity, arrival by ambulance (OR=0.63) and hospital admittance (OR=0.20) were significant predictors of clinical clearance. Patients who arrived by ambulance had 37% decreased odds of clinical clearance without radiography compared to patients who arrived by their own means. Patients who were admitted to the hospital had decreased odds of 80% of being clearance without radiography compared to patients that were not admitted. These factors did function as controls for patient severity as had been intended. For the CT context, the factors used as indicators of patient severity functioned as intended but none of the TPB constructs were relevant.

In general, the TPB model's proposed relationships between the predictors of behaviour and the TPB constructs functioned partially in the CS context but not in the CT context. Perceived behavioural control was not relevant in either context, suggesting that a physician's level of control over performing clinical clearance was not a factor in whether a patient was actually clinically cleared. There was a clear contrast between contexts for the association between intention and clinical clearance. Physicians with higher intention to clinically clear had higher odds of actually clinically clearing in the CS context, but a

physician's level of intention did not influence clinical clearance in the CT context. Our inability to demonstrate this association in the CT context may be due to small sample sizes. On average, a physician in the CS treated more than three times as many patients as a physician in the CT. Thus, we may not have had enough CT patients per physician to provide sufficiently precise measures of CT clinical clearance, thereby preventing the demonstration of a significant association between the intention and behaviour of physicians in CT. Our results provide evidence that TPB explains the behaviour of physicians to clinically clear patients only in CS, but TPB may also have explained clinical clearance in CT had we been provided equivalent sample sizes.

TABLE 10: Generalized Mixed Linear Models Predicting Clinical Clearance without Radiography

Models	C-Spine		CT-Head	
	(Physicians=117, Patients=2260, ICC=0.16)		(Physicians=90, Patients=544, ICC=0.13)	
Variables	OR (95% CI)	P-value	OR (95% CI)	P-value
Intention	1.79 (1.40, 2.29)	<0.01	1.05 (0.87, 1.28)	0.60
Perceived Behavioural Control	0.79 (0.60, 1.03)	0.08	0.92 (0.57, 1.50)	0.74
Arrival by Ambulance	0.24 (0.20, 0.30)	<0.01	0.63 (0.40, 0.98)	0.04
Hospital Admittance	0.18 (0.09, 0.38)	<0.01	0.20 (0.10, 0.39)	<0.01

Objective #4: Did the intervention result in any changes of the TPB constructs?

The distributions of the TPB construct scores of physicians who had completed surveys in both phases were examined before any models were constructed. Table 11 and 12 display the means and standard deviations of each TPB construct score by each phase and group (intervention/control) for the CS and CT contexts respectively. The means of baseline TPB construct scores for intention, attitude, and subjective norms were greater than 6 in the CS context and greater than 5 in the CT context when the maximum score for each measure was 7 in both contexts. Histograms were therefore plotted for the baseline TPB construct scores of each context to examine the extent to which scores exhibited ceiling effects (Figures 21 to 28). From these figures, it is clear that the distributions of intention, attitude, and subjective norms are skewed with many scores at or near the maximum in both clinical contexts. This suggests that ceiling effects within some of the measures may prevent us from discerning any longitudinal changes from the pre-phase to the post-phase of the studies.

Despite the existence of ceiling effects, a mixed model was constructed for each TPB construct (intention, attitude, subjective norms, and perceived behavioural control) in each survey (CS, CT) to evaluate whether any had changed due to the interventions employed in the implementation studies. Tables 13 to 16 present the models constructed to evaluate changes in each TPB construct. Pre-phase scores were significant predictors of post-phase scores for all TPB constructs in both clinical contexts. This was expected since post-phase scores are essentially repeated measures of the pre-phase scores. The intervention/control group did not explain any additional variance over and above the pre-phase scores for any of the TPB constructs in either context. This was consistent with our second hypothesis that the intervention had not significantly changed the TPB constructs in the CT context, but

inconsistent with our first hypothesis that the intervention had significantly changed the TPB constructs in the CS context. Given the success of the CS study and failure of the CT study in reducing radiography, it has been expected that TPB constructs had undergone changes in CS context but not the CT context. The lack of contrast between CS and CT, however, may suggest that any changes in behaviour did not occur through the TPB pathway or that our measures did not have sufficient power to detect such changes. Given the highly skewed measures and the small samples sizes, we are unable to conclude whether any actual changes occurred.

TABLE 11: TPB Construct Scores from C-Spine Survey by Phase and Group (Intervention/Control)

TPB Construct	Mean Score (SD)			
	Control (n=29)		Intervention (n=25)	
	Pre-Phase	Post-Phase	Pre-Phase	Post-Phase
Intention	6.54 (0.49)	6.69 (0.41)	6.58 (0.52)	6.53 (0.84)
Attitude	6.68 (0.43)	6.78 (0.40)	6.52 (0.72)	6.50 (0.76)
Subjective Norms	6.14 (0.71)	6.43 (0.68)	6.10 (0.89)	6.24 (0.99)
Perceived Behavioural Control	5.13 (0.52)	4.77 (0.71)	4.79 (0.63)	4.83 (0.65)

TABLE 12: TPB Construct Scores from CT-Head Survey by Phase and Group (Intervention/Control)

TPB Construct	Mean Score (S.D.)			
	Control (n=25)		Intervention (n=25)	
	Pre-Phase	Post-Phase	Pre-Phase	Post-Phase
Intention	5.83 (1.25)	5.90 (1.03)	5.14 (1.43)	5.39 (1.66)
Attitude	5.76 (0.97)	5.54 (1.28)	5.36 (1.35)	5.10 (1.59)
Subjective Norms	5.46 (0.99)	6.08 (1.10)	5.04 (1.35)	5.58 (1.66)
Perceived Behavioural Control	5.02 (0.72)	4.87 (0.63)	4.84 (0.51)	4.85 (0.62)

Figure 21: Baseline Attitude Scores for CS Context

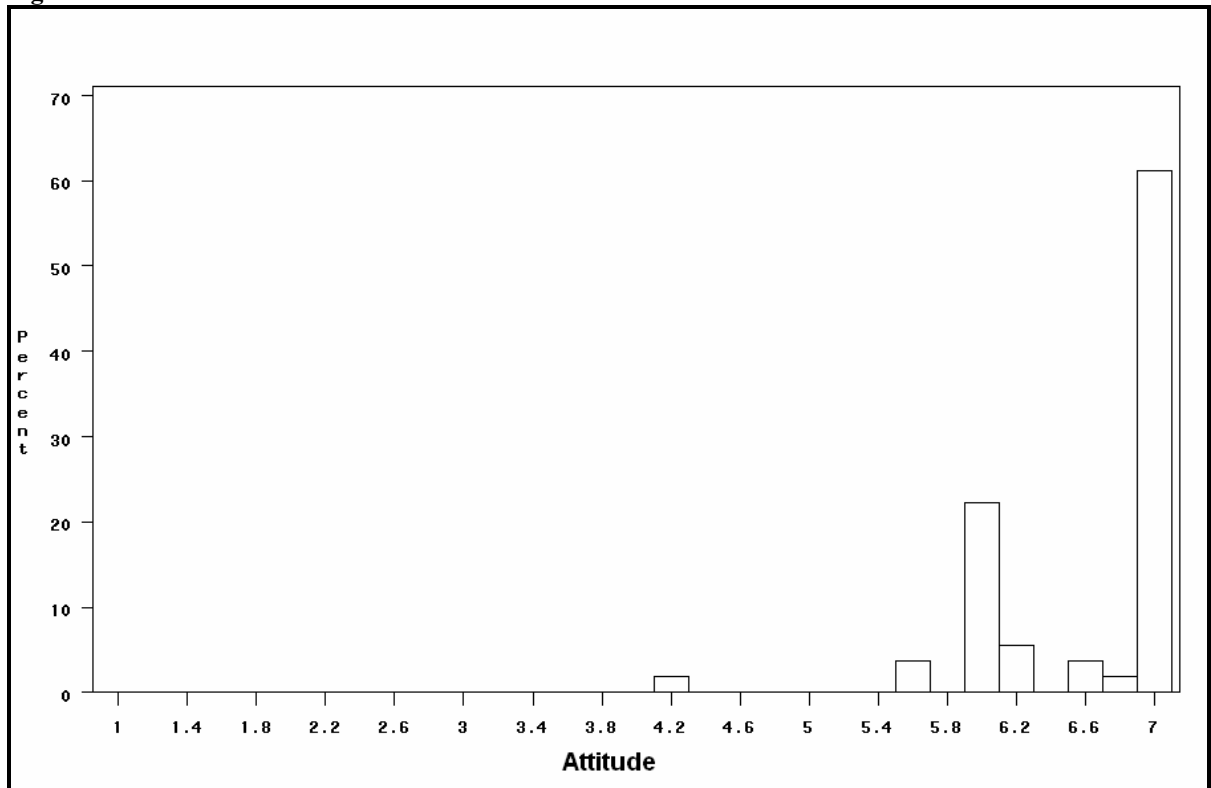


Figure 22: Baseline Attitude Scores for CT Context

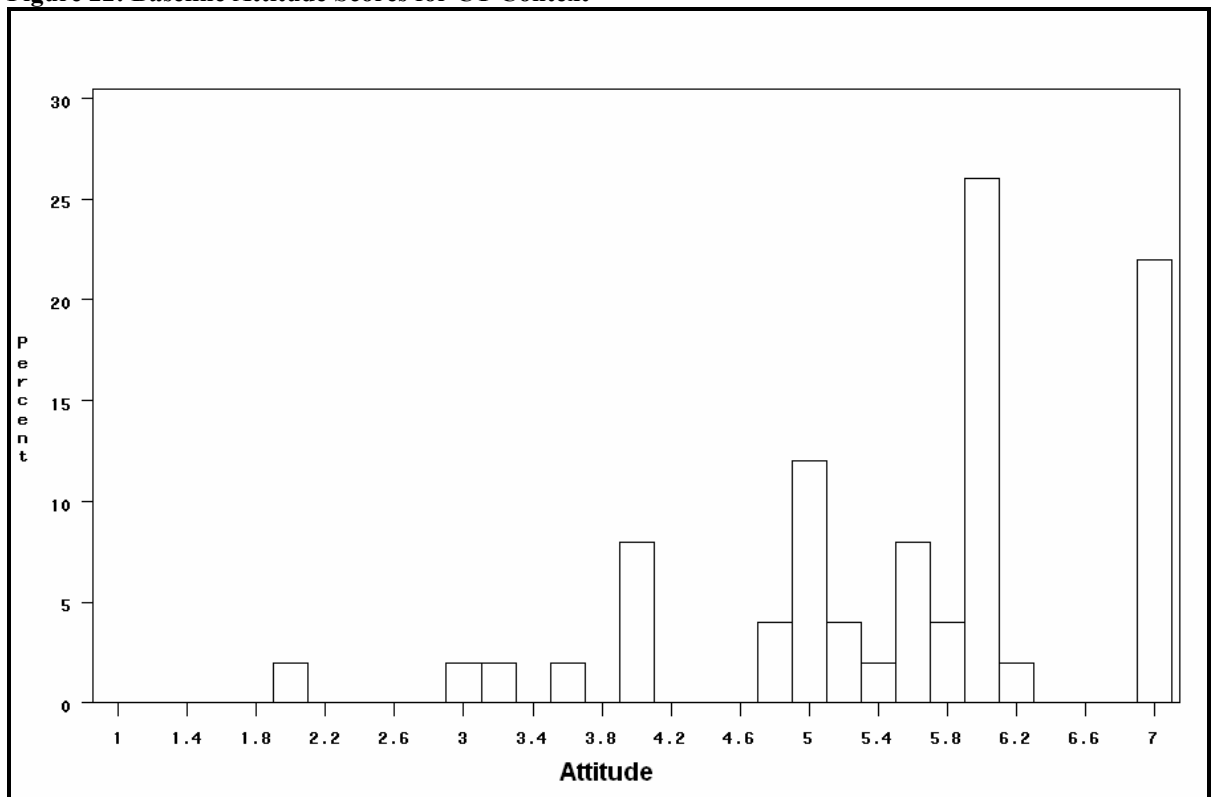


Figure 23: Baseline Subjective Norms Scores for CS Context

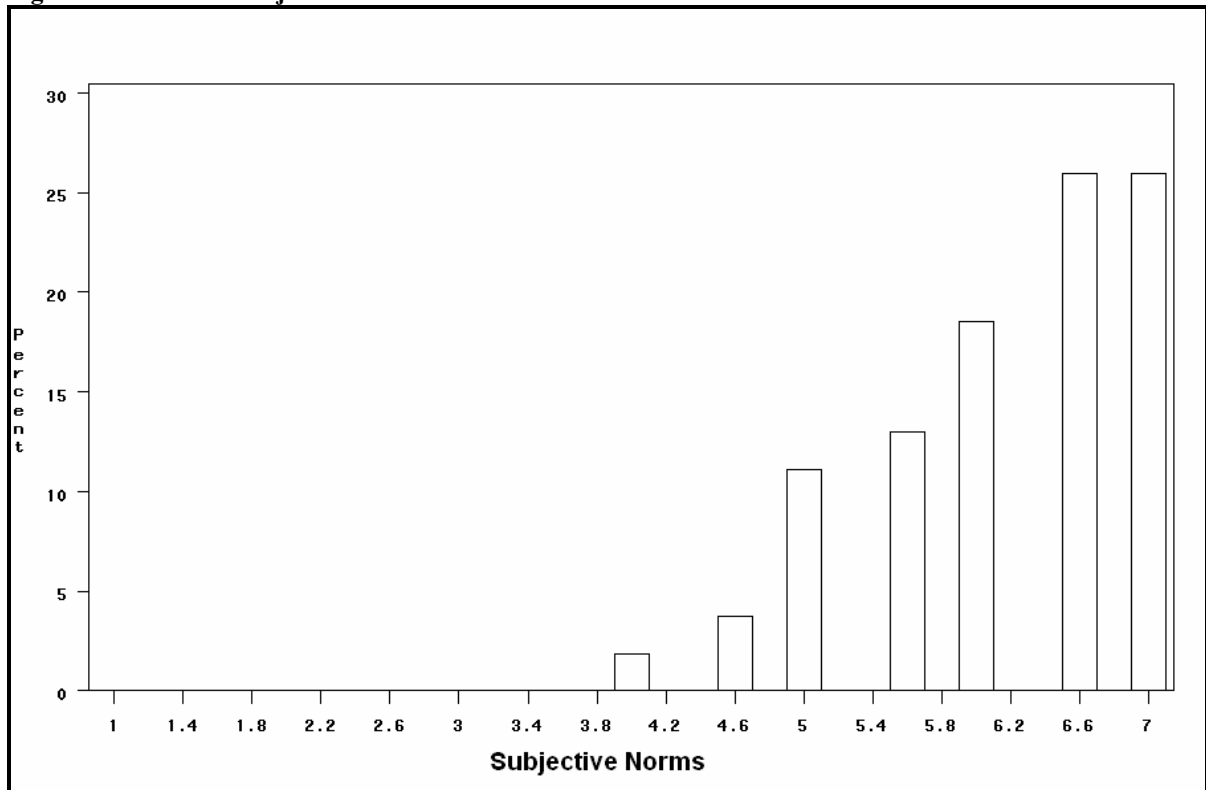


Figure 24: Baseline Subjective Norms Scores for CT Context

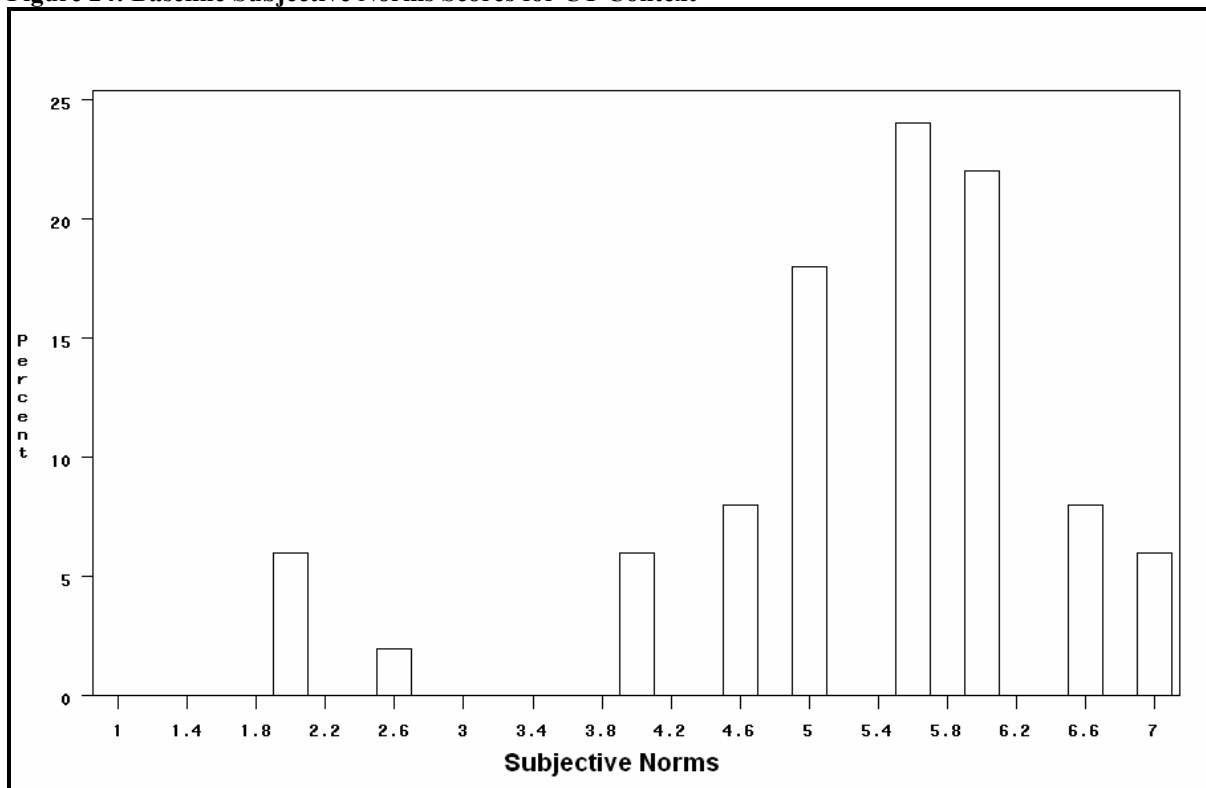


Figure 25: Baseline Perceived Behavioural Control Scores for CS Context

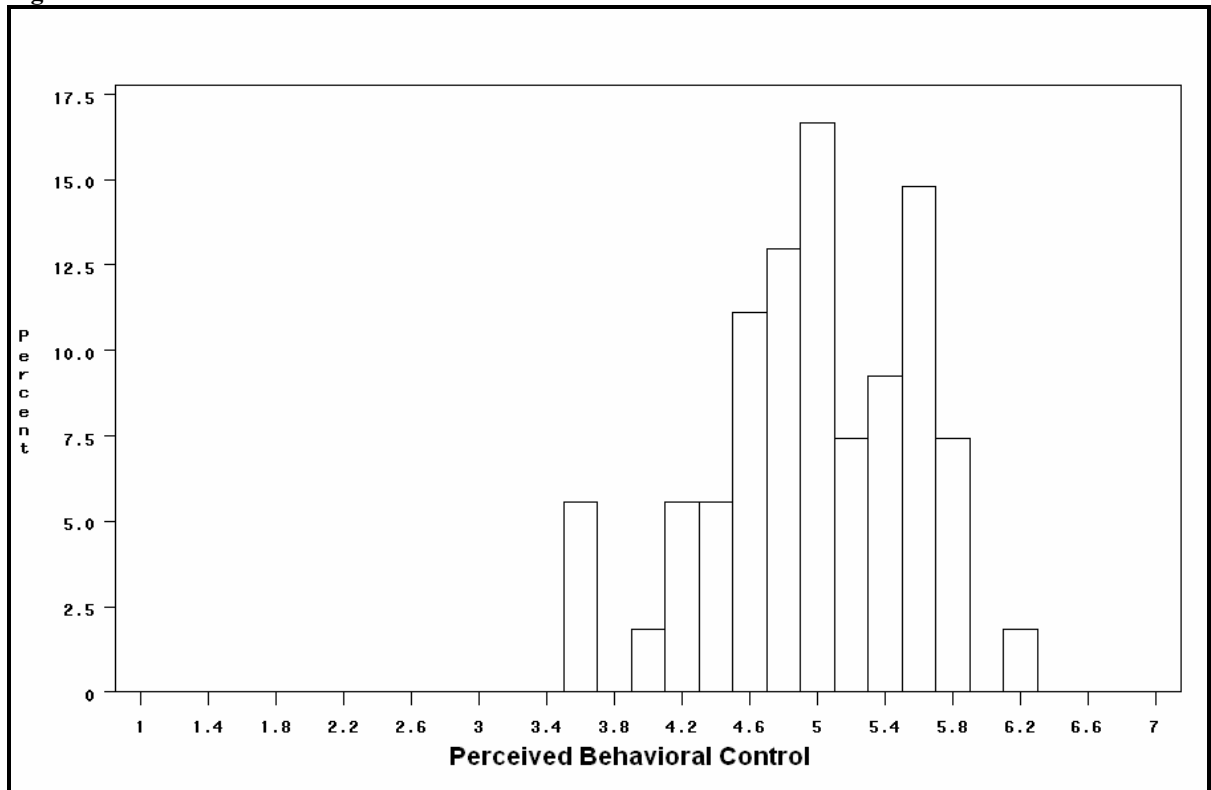


Figure 26: Baseline Perceived Behavioural Control Scores for CT Context

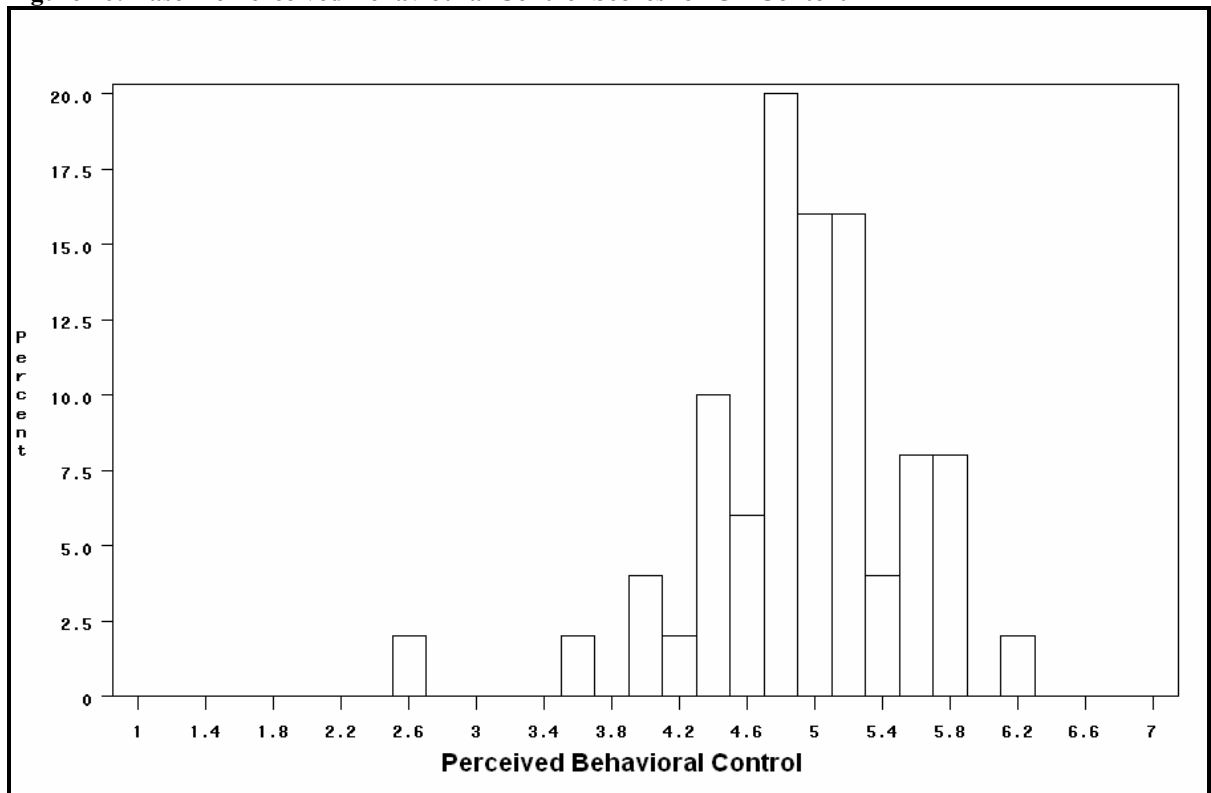


Figure 27: Baseline Intention Scores for CS Context

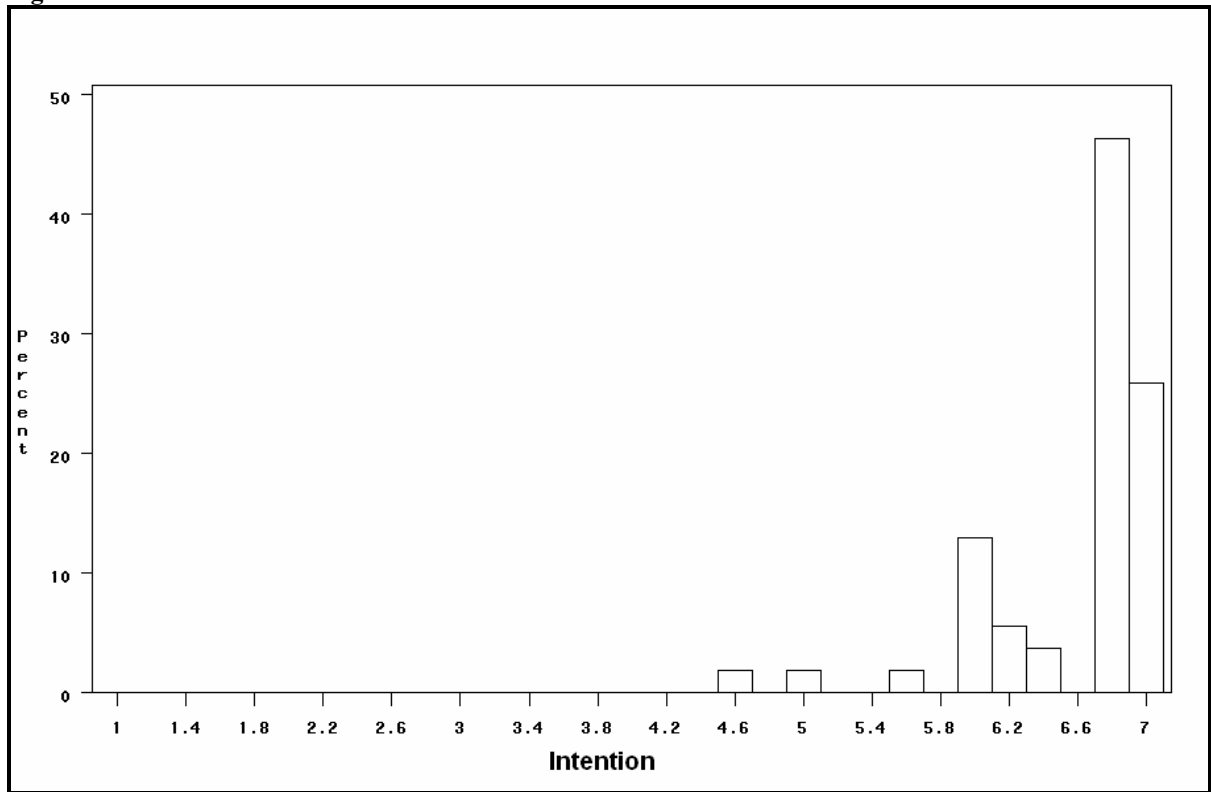


Figure 28: Baseline Intention Scores for CT Context

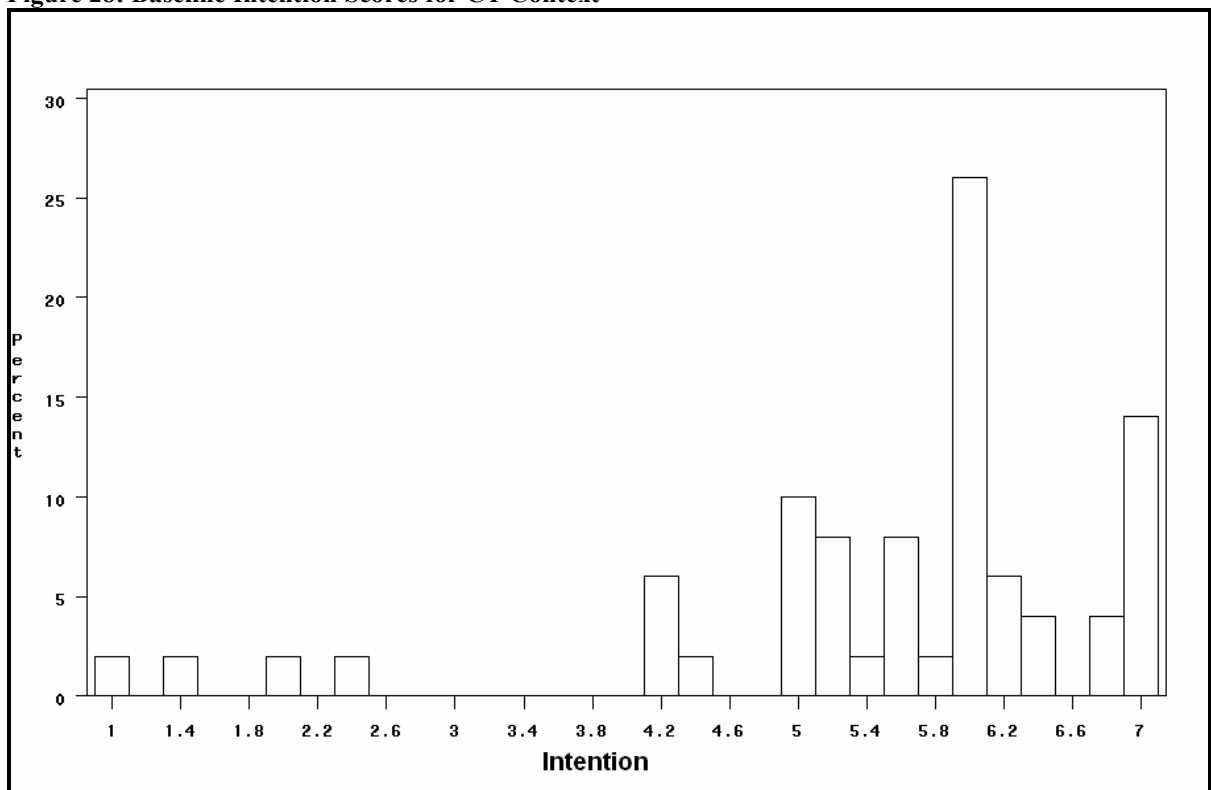


TABLE 13: Mixed Linear Models Predicting Post-Phase Attitude Scores using Pre-Phase Score and Group (Intervention/Control)

Model	C-Spine (n=54, ICC=0.07)		CT-Head (n=50, ICC=0)	
Variables	Regression Estimate (95% CI)	P-value	Regression Estimate (95% CI)	P-value
Intercept	2.28 (0.72, 3.84)	<0.01	3.21 (1.12, 5.29)	<0.01
Intervention/Control	-0.26 (-1.51, 0.99)	0.23	-0.48 (-1.66, 0.71)	0.24
Pre-Phase Attitude Score	0.68 (0.45, 0.90)	<0.01	0.41 (0.06, 0.77)	0.03

TABLE 14: Mixed Linear Models Predicting Post-Phase Subjective Norms Scores using Pre-Phase Score and Group (Intervention/Control)

Model	C-Spine* (n=54, ICC=0)		CT-Head (n=50, ICC=0.10)	
Variables	Regression Estimate (95% CI)	P-Value	Regression Estimate (95% CI)	P-Value
Intercept	3.79 (2.11, 5.47)	<0.01	3.55 (1.67, 5.43)	<0.01
Intervention/Control	-0.17 (-0.60, 0.25)	0.41	-0.36 (-1.18, 0.46)	0.34
Pre-Phase Subjective Norms Score	0.43 (0.16, 0.70)	<0.01	0.47 (0.14, 0.80)	<0.01

*Variance constrained to positive values to allow for convergence

TABLE 15: Mixed Linear Models Predicting Post-Phase Perceived Behavioural Control Scores using Pre-Phase Score and Group (Intervention/Control)

Model	C-Spine (n=54, ICC=0.15)		CT-Head* (n=50, ICC=0)	
Variables	Regression Estimate (95% CI)	P-Value	Regression Estimate (95% CI)	P-Value
Intercept	2.17 (0.58, 3.76)	<0.01	4.05 (2.58, 5.53)	<0.01
Intervention/Control	0.22 (-0.26, 0.70)	0.31	0.01 (-0.35, 0.37)	0.96
Pre-Phase Perceived Behavioural Control Score	0.51 (0.21, 0.81)	<0.01	-0.84 (-1.12, 0.37)	<0.01

*Variance constrained to positive values to allow for convergence

TABLE 16: Mixed Linear Models Predicting Post-Phase Intention Scores using Pre-Phase Score and Group (Intervention/Control)

Model	C-Spine (n=54, ICC=0)		CT-Head (n=50, ICC=0.13)	
Variables	Regression Estimate	P-Value	Regression Estimate	P-Value
Intercept	2.51 (0.45, 4.58)	0.02	4.00 (2.23, 5.77)	<0.01
Intervention/Control	-0.28 (-1.67, 1.12)	0.24	-0.27 (-1.24, 0.70)	0.54
Pre-Phase Intention Score	0.64 (0.33, 0.95)	<0.01	0.33 (0.04, 0.62)	0.03

Objective #5: Does changes in TPB constructs predict changes in the rate of clinical clearance?

The results from the generalized linear mixed model constructed for each clinical context to evaluate whether changes in the TPB constructs predicted changes in clinical clearance are presented in Table 17. Contrary to our original proposed analysis, perceived behavioural control and its interactions were not entered into either model since it was demonstrated not to be associated with clinical clearance in earlier analysis (objective #3) for either context. Our analysis therefore focused on intention scores. This analysis had been planned expecting that objective #4 would have demonstrated a contrast between contexts in which the intervention had significantly changed the constructs in CS but not CT. Although we were unable to demonstrate this contrast, it was still important to examine whether changes in clinical clearance were associated with changes in the TPB constructs since this would allow us to examine whether it was possible to change clinical clearance through the TPB constructs. In the CT context, time-varying levels of intention were not a significant predictor of clinical clearance. This suggests that changes in CT clinical clearance are not explained by changes in intention or that our measures may not have sufficient power to detect significant changes in the CT TPB constructs. As had been discussed earlier (objective #3), it is possible that our small sample sizes may have prevented the demonstration of any significant association in the CT context. Physicians treated two to three times more CS patients than CT patients in this analysis, which may suggest that we may not have had enough CT patients per physician to provide sufficiently precise measures of CT clinical clearance.

In the CS context, the three-way interaction of intention, group, and phase as well as the main effect of intention was significant suggesting that intention was a significant

predictor of clinical clearance, but that this association varied with group and phase (Table 17). Increases in intention predicted significant increases in the odds of clinical clearance within the control group (OR=2.03; 95% CI: 1.26-3.27) but not the intervention group (OR=1.20; 95% CI: 0.87-1.64) (Table 18). This may have been the product of a ceiling effect in intention measures since intention measures at or near the ceiling could not increase in accordance with increases clinical clearance. This effect would have been more pronounced in the intervention group where greater increases in clinical clearance occurred. As a result, changes in the intervention group would have appeared insignificant in contrast to changes in the control group. This is demonstrated when examining intention between phases of each group (Table 18). For the intervention group, the odds of clinical clearance increased with the intention score in both the pre- and post-phase, but the increase in the post-phase was less than in the pre-phase (OR=0.66 post vs. pre). In the control group, higher intention was associated with less likelihood to clinically in the pre-phase, but with more likelihood to clinically clear in the post-phase (OR=2.07 post vs. pre). This is likely the explanation for the 3-way interaction. Figure 29 shows changes in rates of clinical clearance plotted against changes in intention for physicians who treated at least five patients in each phase. This plot demonstrates that in the absence of a ceiling effect, increases in intention may have predicted increases in clinical clearance across both groups. The red regression line for physicians who had baseline intention scores at or near the maximum score of 7 (>6.7) was practically flat, suggesting no association between intention and clinical clearance when there was a ceiling effect. In contrast, the blue regression line for physicians who had baseline intention scores <6.7 had a positive slope, suggesting that increases in intention predicted increases in clinical clearance when there was no ceiling effect. Thus, changes in intention predicted significant changes in clinical clearance only

within the control group of the CS context but a ceiling effect may have prevented the demonstration of this same effect in the intervention group.

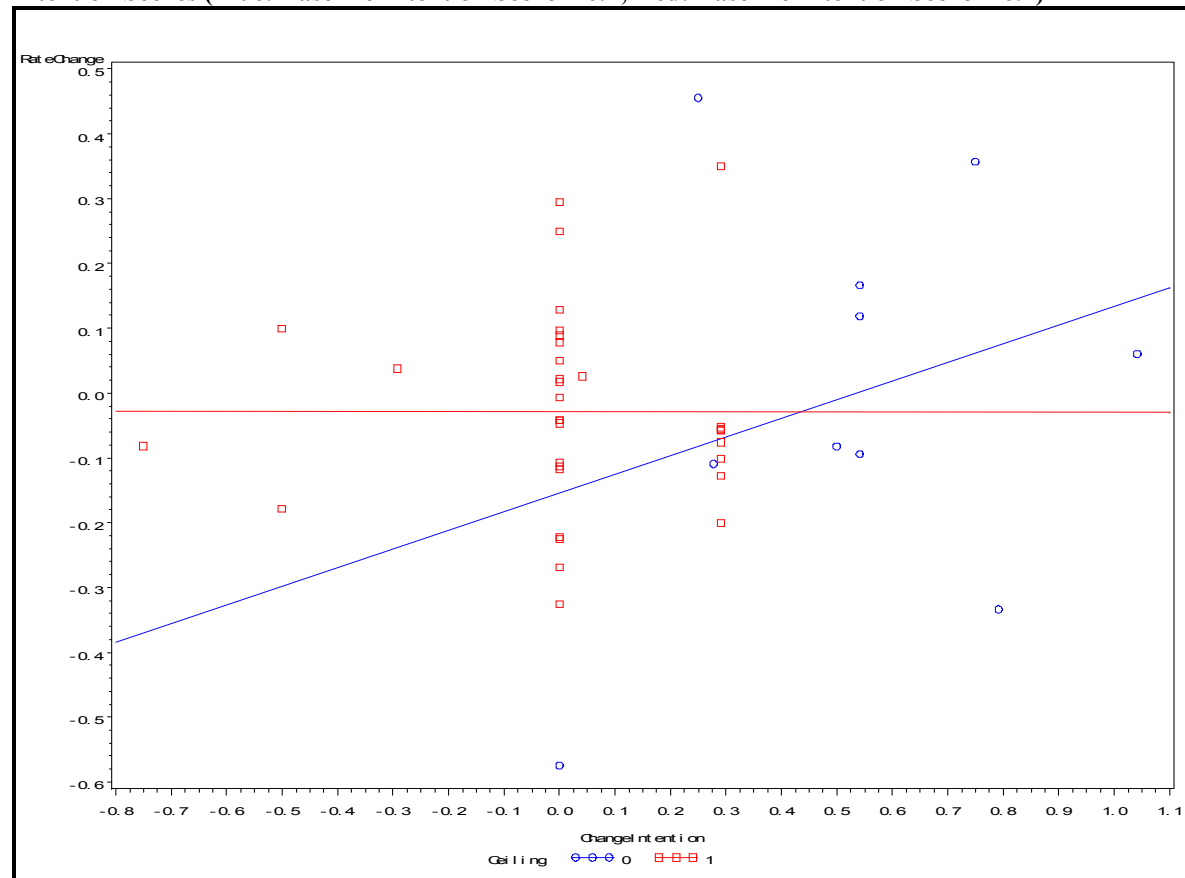
TABLE 17: Generalized Linear Mixed Models Predicting Clinical Clearance without Radiography Using Time-Varying TPB Constructs

Variables	CS (Physicians=117, Patients=3276, ICC=0.16)		CT (Physicians=90, Patients=1029, ICC=0.14)	
	Estimate	P-Value	Estimate	P-Value
Intercept	-2.335	0.06	-0.236	0.76
Intention	0.497	<0.01	-0.032	0.80
Group	-0.642	0.69	0.324	0.75
Phase	-3.213	0.29	0.713	0.61
Group*Phase	8.452	0.02	-1.741	0.32
Arrival By Ambulance	-1.489	<0.01	-0.634	<0.01
Hospital Admittance	-2.169	<0.01	-1.492	<0.01
Intention*Group	0.045	0.85	0.083	0.62
Intention*Phase	0.421	0.35	-0.094	0.69
Intention*Group*Phase	-1.151	0.03	0.107	0.72

TABLE 18: Examination of Three-way Interaction for Generalized Linear Mixed Model in CS Context

Comparisons	OR (95% CI or P-Value)
Intervention vs. Control	1.12 (0.45, 2.80)
Post-Phase vs. Pre-Phase	1.01 (0.80, 1.25)
Unit Increase in Intention	
Intervention Group	1.20 (0.87, 1.64)
Control Group	2.03 (1.26, 3.27)
Post-Phase Intention vs. Pre-Phase Intention	
Intervention Group	0.66 (p=0.56)
Control Group	2.07 (p=0.28)

Figure 29: Changes in Clinical Clearance versus Changes in Intention for the CS Context by Baseline Intention Scores (Blue: Baseline Intention Score < 6.7; Red: Baseline Intention Score > 6.7)



DISCUSSION

This study took advantage of a pair of ongoing CDR implementation studies at twelve Canadian EDs. The two CDRs being implemented, the Canadian C-Spine (CS) and Canadian CT-Head rule (CT), are two rules that purport to improve the efficiency of radiography use by emergency physicians in the treatment of neck injuries and minor head injuries respectively. Theory-based surveys that were designed to assess the utility of TPB constructs in these contexts were embedded within the studies. These surveys were administered before and after the intervention in each arm of the studies, thereby providing us with longitudinal measures of the constructs that could be examined with respect to the longitudinal measures of physician behaviour captured within the implementation studies. Unexpectedly, only the implementation study for the CS rule showed a significant reduction in radiography ordering rates while the implementation study for the CT rule failed to show any significant impact at all.

There are several novel components to this study that make it a unique contribution to the literature. This project represents the first time psychological theory has been systematically applied to the problem of uptake of CDRs. Theories allow us to investigate the possible underlying active components of an intervention and explore possible causal relationships. Knowledge of the active components involved in the uptake of CDRs can guide future implementation efforts by providing us with potential targets for our interventions. An understanding of the causal pathways through which these active components function can then allow us to generalize the results of successful implementations and identify the reasons for failed implementations. This first time use of

theory in the context of CDR implementation is therefore a significant step towards improving the uptake of CDRs.

Second, it is unique in the literature to have two comparable rules (CS, CT) undergoing practically identical implementations at essentially the same time. Both rules are aimed at improving inefficient use of radiography in EDs, and underwent the same methodology of development in derivation and prospective validation. Their implementation studies employed the same sets of strategies (i.e. manuscripts, pocket cards, posters, requisition forms, and a teaching session) at the same set of twelve hospitals, with intervention hospitals in one study serving as controls in the other study. In maintaining all these characteristics as similar as it is possible for these types of studies, we are essentially provided with a natural experiment where the independent variable was the CDR and dependent variable was clinical clearance. Replication of these circumstances would require tremendous long-term planning and resources. CDRs can take years to derive, validate, and implement, and can involve thousands of patients. The circumstances presented in this study in which two comparable rules underwent practically identical processes of development and implementation in parallel may not occur again.

Third, the drastically different results from the two implementation studies provided a unique opportunity to examine whether TPB constructs could explain for differences in the uptake of CDRS, and thereby differentiate between successful and an unsuccessful implementations. If the theoretical constructs examined are responsible for changes in behaviour than we would expect that any differences in the outcomes of these similar studies to stem from differences in how the intervention was able to change the constructs. For this to be the case, the constructs in the successful implementation (CS) would have had to undergone greater changes than in the unsuccessful implementation (CT). It cannot however

be ascertained beforehand that practically identical implementations of two comparable rules will produce such drastically different results. We were rather fortunate that theory-based surveys were embedded in each implementation, putting us in the position to evaluate the utility of TPB once the unexpected results occurred. All these unique conditions collectively make this a novel study that can provide important contributions to the literature.

The first objective of this study was to evaluate whether the TPB methodology yielded reliable and valid measures of the TPB constructs. In accordance with the first hypothesis for this objective, our study showed that the TPB methodology yielded internally consistent measures of the TPB constructs across both clinical contexts.⁴⁷ Adequate internal consistency was achieved for each of the TPB constructs with use of all but one item. The only item not included in analysis for either survey (“People Important to Me think I should *‘clinically clear the C-Spine’* / *‘manage patients without CT’*”) was likely problematic because it was the first item with a response scale of reverse polarity on each survey. The removal of this item meant that subjective norms scores were only based on two items, which may have led to less variability within the score than desired, but it is unlikely to bias the score unless these important individuals to whom the item makes reference are not professional colleagues or members of the CAEP which were examined by the two remaining subjective norms items. Several imperfect solutions to this problem have been proposed. One could not reverse the polarity of any items, but this approach is known to lead to acquiescence bias, where respondents tend to answer all items in the same manner regardless of whether items actually changed.⁶³ Another alternative would be to have response scales switch polarities earlier and more frequently to negate for the possibility of participants overlooking the polarity of the response scales. Such an approach would make the survey more complex for respondents, leading to potential survey fatigue and a decrease

in survey completions. Banked polarity reversals, where complete sections alternate in polarity, would be an equitable compromise that would be recommended for future studies.

Validation of all the constructs was not possible; only a limited validation of intention could be feasibly performed. Of the four TPB constructs, intention is the most important as it acts as a mediator through which the other TPB constructs act on the behaviour of interest, and is one of two direct predictors of the behaviour. Without valid measures of intention, any evaluation of the entire TPB model would be problematic. Given that there were no gold standards by which to evaluate the validity of the TPB constructs, we were able to partially demonstrate through hypothesis testing that intention measures were valid. In accordance with our hypothesis, physicians that were less favorable to clinically clearing patients were also more likely to indicate potential barriers. Given the standardized TPB methodology used in our study and this limited demonstration of validity for the most important TPB construct, we reasoned that our evaluation of the TPB model using these measures would be valid.

For the second objective, we evaluated whether the TPB constructs (attitude, subjective norms, and perceived behavioural control) predicted intention to clinically clear without radiography. In accordance with the TPB model, it was hypothesized that attitude, subjective norms, and perceived behavioural control favorable to clinical clearance would predict greater intention to clinically clear across both contexts. Attitude refers to the degree to which an individual positively or negatively values their performance of the behaviour. Subjective norms are an individual's perception of whether people of significance to them believe the behaviour should be performed. Perceived behavioural control refers to an individual's perceived ease or difficulty in performing the behaviour. For TPB to explain the

behaviour of clinical clearance in the contexts of our study, intention would have to be associated with one or more of these constructs.

Intention to clinically clear without radiography was associated with the same TPB constructs across both clinical contexts. Attitude and subjective norms were significantly associated with intention to clinically clear in each of the CS and CT contexts. It was demonstrated that the greater a physician positively values clinical clearance, or the greater the physician perceives that people of importance to them value clinical clearance, the greater their intention to clinically clear. Thus, there are two potential TPB pathways through which an intervention may improve intention to clinically clear in the CS and CT contexts. On the other hand, perceived behavioural control was not significant in either context, suggesting that a physician's perceived behavioural control over clinically clearing does not influence their intention to clinically clear. The lack of a significant association between perceived behavioural control and intention may be explained by the independent nature of emergency physicians who tend to work alone. They may therefore perceive the clinical clearance of patients to be at their own discretion and not influenced by any outside constraints. In such circumstances, we would still expect intention to be significantly associated with attitudes and subjective norms, but not perceived behavioural control.

The influence of the TPB constructs that were significantly associated with intention was not uniform across both clinical contexts. It would appear that CS is influenced more by attitudes, while CT is influenced much more by subjective norms. In which case, we may have greater success improving intention within the CS context by attempting to improve the attitudes of individual physicians, whereas in the CT context greater success may be achieved by improving subjective norms. These differences may help explain why the intervention employed in these implementation studies had different outcomes. The

intervention may have improved a physician's intention to clinically clear by improving attitudes towards clinical clearance, in which case it would have had a greater impact in the CS context than in the CT context, subsequently resulting in a significant reduction of radiography in the CS but not CT.

For the third objective, we evaluated whether the TPB constructs (intention, perceived behavioural control) predict actual clinical clearance across both contexts. According to TPB, behaviour is primarily determined by one's level of intention to perform the behaviour, and this relationship is moderated by one's actual control over performing the behaviour. Since actual control is difficult to measure, the theory posits that perceived behavioural control be used as a proxy for actual control. Thus, it was hypothesized that higher intention to clinically clear and greater perceived behavioural control over clinical clearance would predict greater actual clinical clearance across both contexts. As in the analysis of predictors for intention, perceived behavioural control was also not a significant predictor of actual clinical clearance in either context, suggesting that the level of control a physician has over clinically clearance does not influence their likelihood of clinical clearing patients.

There was a stark contrast between the contexts in the evaluation of intention as a predictor of clinical clearance. Greater intention to clinically clear was associated with greater actual clinical clearance in the CS but not the CT. For CT, there was no significant association, suggesting that clinical clearance was occurring regardless of the level of intention to clinically clear by a physician or that our measures were not sufficiently sensitive to detect an association. If intention and perceived behavioural control are not associated with CT clinical clearance than factors outside of TPB are responsible for the behaviour. Limitations in our measurements may however have prevented the demonstration

of any significant association. Ceiling effects in intention measures combined with the small numbers of CT patients per physician limited the amount of possible variation in intention scores and precision of behaviour measurements. Although CS measures of intention also exhibited ceiling effects, physicians in the CS study treated on average more than three times as many patients as physicians in the CT study. We speculate that an association between intention and CT clinical clearance may have been demonstrated if physicians had treated greater numbers of CT patients, thereby providing us with more precise measures of the behaviour.

For the fourth objective, we evaluated whether the strategies employed within the implementation studies resulted in any changes to the TPB constructs. Given that the implementation studies had reduced CS radiography but not CT radiography, we hypothesized that the CS TPB constructs had undergone changes while the CT constructs had not. Counter to our hypotheses, no contrast was demonstrated between the two contexts. No significant changes in the TPB constructs were demonstrated in either context. This suggests that the intervention either worked through another pathway or that our measures were not sensitive enough to detect any changes in the TPB constructs.

We believe that small sample sizes and ceiling effects within the measures prevented the detection of any changes in the TPB constructs. There were only a limited number of physicians who were eligible to provide longitudinal measures in this study. Physicians had to have been active at the hospitals involved in the implementation trials during the randomization of the surveys, the pre-phase survey administration, and the post-phase survey administration. These eligibility requirements resulted in small potential sample sizes on which to perform our analysis. As is usually the case with any longitudinal study, drop-outs were observed from the pre-phase to the post-phase which exacerbated the sample size

problems. Ceiling effects in the TPB construct measures compounded the problem by limiting the amount of variation in our measures. The measures of many physicians were at or near the maximum score already in the pre-phase, meaning that longitudinal increases were not even possible in many cases. To make matters worse, the ceiling effect was more pronounced in the CS context, where we had expected to detect more notable changes in the TPB constructs if the intervention had indeed functioned through the TPB model. Given the small sample sizes and ceiling effects, it is unlikely that we would have been able to demonstrate any significant changes that may have occurred. In future studies, it would be advisable to ensure very large sample sizes so that we may detect small changes and potentially compensate for ceiling effects in the measures.

Although it may be possible to change radiography ordering behaviour through the TPB constructs, it is extremely unlikely to be the explanation for the drastically different outcomes between the implementation studies. Measures of intention to clinically clear without radiography were already very high during the pre-phase of both implementation studies, suggesting that the potential improvement in clinical clearance from changes in the TPB constructs was minimal. Thus, the significant changes in CS clinical clearance must be primarily the result of changes in constructs not contained in the TPB model.

For the fifth and final objective, it was evaluated whether changes in the TPB constructs predicted changes in clinical clearance for each context. TPB posits that behaviour is determined by one's intention to perform the behaviour and one's control over performance of the behaviour, where perceived behavioural control is used as a proxy for actual control. Given that perceived behavioural control was already demonstrated not to be relevant in either context, only changes in intention were examined. In accordance with the

TPB model, it was hypothesized that changes in intention to clinically clear would predict actual changes of clinical clearance.

Since our measures of the TPB constructs were not associated with CT clinical clearance in earlier analysis, it comes as no surprise that changes in the TPB constructs did not predict changes in CT clinical clearance either. This would suggest that clinical clearance may not be acting through the TPB pathway for the CT context or that our measures were not sufficiently sensitive to detect any changes. Given that CT clinical clearance did not undergo significant changes in the implementation study and the TPB constructs did not appear to undergo significant changes either, we suspect that it would have been difficult to demonstrate any associations between changes in the TPB constructs and CT clinical clearance. The lack of significant change in CT clinical clearance and TPB constructs also suggests that there are no important differences between the pre-phase and post-phase. Thus, this longitudinal analysis can be simply reinterpreted as an evaluation of the association between TPB constructs and CT clinical clearance, which had been performed already for the third objective. The advantage in reexamining this objective using this longitudinal model for CT clinical clearance is the added sample size, which had been a concern in the earlier analysis. Given the greater sample size in this longitudinal analysis, it becomes clear that CT clinical clearance cannot be explained by the TPB constructs.

For the CS context, the association between changes in intention and changes in clinical clearance was not uniform across the intervention and control groups. Increases in intention predicted significant increases in clinical clearance within the control group but not the intervention group. This unexpected result was believed to be the product of ceiling effects in the measures of the TPB constructs, which would have been more pronounced in the intervention group where greater increases in CS clinical clearance had occurred. In the

absence of ceiling effects, we believe that increases in intention would have been associated with increases in CS clinical clearance across both the intervention and control groups. If such is the case, changes in the TPB constructs through an intervention would produce changes in clinical clearance. Nevertheless, improving CS clinical clearance through changes in the TPB constructs is unlikely to be an effective approach given the already high levels of intention to clinically clear in the CS context.

Significance

This study is the first time psychological theory has been systematically applied to the problem of the uptake of CDRs. We applied TPB to the implementation studies of two comparable rules; the Canadian C-Spine and CT-Head Rules. TPB is the most well studied theory in health research, having been tested in many different contexts. The parallel implementation studies of these two comparable rules provided a unique opportunity to evaluate the utility of TPB in explaining the uptake of CDRs. This is an important first step in understanding the pathways through which implementation strategies may change behaviour and thereby facilitate the incorporation of CDRS into clinical practice.

Our study has several important strengths that separate it from many other TPB studies. We evaluated all proposed relationships with the TPB model, whereas many studies simply evaluate intention rather than the actual behaviour of interest.⁵² The lack of association between intention and CT clinical clearance in this study illustrates how measuring intention can be inadequate if our goal is to understand behaviour. Many of the studies that do examine behaviour, however, simply look at self-reported measures that are open to biases. Our study had the advantage of relying on objective behavioural measures of

clinical clearance from the implementation studies that involved thousands of patients. If our aim is to fully understand the behaviour of clinical clearance, the entire pathway from the constructs to the actual behaviour needs to be examined.

The use of hierarchical models in the evaluation of TPB model was an innovative technique. In evaluating the real world impact of the CDRs, entire hospitals were randomized to the intervention or control group; what is habitually known as a cluster-randomized trial. The intervention was therefore applied to entire hospitals with the aim of changing the behaviour of physicians within these hospitals. The behaviour of these physicians was then subsequently demonstrated at the patient level by whether they clinically cleared patients without radiography. Hospitals did not have the same number of physicians, nor did physicians necessarily treat the same number of physicians within the studies. It was therefore vital for us to use hierarchical modeling that could account for the clustering of measures by hospital and physician. Hierarchical modeling allows us to examine the TPB model within the real world circumstances of implementation studies, where measures cannot be ascertained to be completely independent of each other.

Many studies also simply examine simple correlations between constructs and intention or behaviour, which does not adequately describe potential causal pathways.⁸⁰ Correlational data does not tell us whether the TPB constructs are the cause of the behaviour of interest or whether the TPB constructs are actually a product of performing the behaviour.⁸¹ Had we relied solely on the correlational data from the pre-phase of each study, we may have erroneously concluded that the intervention had changed TPB constructs in CS but not the CT. In examining the longitudinal changes in the TPB constructs and behaviour of interest simultaneously, we showed that the TPB constructs may not have changed significantly in either study and that the differing results cannot be explained through TPB.

The majority of studies that test theories in the area of health research, however, have relied solely on correlational data.^{80;82} More careful attention should be paid to actual changes in constructs and behaviour over time if we wish to actually understand the utility of a theory in explaining behaviour change.

In examining the TPB model with respect to both CS and CT clinical clearance, this study examined two similar behaviours rather than one as in the majority of behaviour change studies. As a result, we were able to demonstrate how even the most similar behaviours can behave very differently. Attitude and subjective norms were significantly associated with intention to clinically clear without radiography across both contexts. Intention in turn was demonstrated to be significantly associated with actual clinical clearance in the CS context, but not the CT context. This suggests that improving the attitudes and subjective norms of physicians will only lead to increases in clinical clearance for the CS context. Thus, even extremely similar behaviours cannot be assumed to behave exactly in the same manner. This demonstrates the complexity of behaviour change and the necessity to examine theories across different behaviours and contexts.

Limitations

This study has several limitations which prevent us from conclusively asserting whether TPB can or cannot explain for differences in the uptake of the CDRs in this study. We were unable to extensively examine reliability of the TPB constructs or the validity of all the TPB constructs. Although we were able to demonstrate the partial validity of intention through hypothesis testing, the validity of the other TPB constructs (attention, subjective norms, perceived behavioural control) were not examined. This could potentially suggest

that measures of these latter constructs were not valid representations of the constructs in the TPB model. Given the extensive use of the standardized TPB survey methodology used within this study, it is unlikely that our TPB construct measures were not reliable or not valid but it is important to be aware of the possibility.

Ceiling effects within our TPB construct measures may have influenced analysis throughout our study. These effects were more pronounced within the CS in comparison to the CT, which prevented us from potentially pooling CS and CT data. Ceiling effects limit the potential variation in the measures, and may have led to false contrasts between the clinical contexts. These ceiling effects likely distorted the estimates of our models that evaluated the relationships of the TPB model, since our models are premised on having normally distributed measures. The most critical consequences from ceiling effects likely occurred in the longitudinal analysis. In limiting the amount of possible variation in the construct measures, ceiling effects made it difficult to ascertain whether the intervention had changed TPB constructs in the intervention group in comparison to the control group. It likely also made it difficult to evaluate any associations between changes in the TPB constructs and changes in clinical clearance. The measures of physicians at or near the maximum score could not undergo increases that corresponded to any increases in clinical clearance. This may have made valid associations appear non-significant; which we suspect occurred in our last objective where increases in intention were associated with CS clinical clearance in the control group but not the intervention group. Careful consideration of the ceiling effects had to be taken into account in the interpretation of our analysis throughout the study.

To avoid possible problems stemming from ceiling effects in our measures, it may be advisable to focus on CDRs which are not already viewed in such a positive manner at

baseline or to adjust our survey items. The latter option is more realistic since we cannot wait for CDRs to meet our specific requirements when it takes years for CDRs to undergo development and implementation. Moreover, CDRs that are positively viewed by physicians are more likely to be developed by researchers, and is often cited as a necessary requirement in the CDR methodology of development.³⁰ In order to continue to utilize TPB in the context of CDRs, it is necessary to move away from the standardized TPB survey methodology while keeping the overlaying framework. This implies piloting survey items that tap the same constructs but in a manner which reduces the likelihood of responses near or at the maximum score.

Small sample sizes made it difficult to demonstrate evidence of associations and changes within several of our objectives. Although both implementation studies encompassed essentially the same time periods, the number of patients included in each study differed immensely. Among the physicians who responded to the TPB surveys, more than 3 times as many patients were treated for the CS context than in the CT context. This resulted in small numbers of CT patients per physician that made it difficult to achieve precise measures of CT clinical clearance that could be compared between physicians or longitudinally over time. For clinical contexts that are rare such as CT, it would be advisable to ensure that the phases of a study are sufficiently long so as to capture enough patient cases from which we can derive precise measures of physician behaviour.

Longitudinal analysis that formed the basis of our last two objectives was likely also limited by the small sample sizes of physicians. Although there were over 200 physicians initially randomized to each survey, low response rates, losses to follow-up, and the lack of behaviour data for some survey respondents resulted in small sample sizes for the longitudinal analysis of each study. There were only 52 (24 Intervention; 28 Control) and 47

(22 Intervention; Control 25) respondents with survey and behaviour data in both phases for the CS and CT respectively. Some hospitals did not even contribute any physician surveys to the post-phases of the studies. These small sample sizes made it more difficult to detect longitudinal changes, which had already been made difficult by ceiling effects that had limited the potential amount of variation in our measures. Moreover, physicians that participated in both phases of the surveys are likely to be more regular or active physicians at their hospitals, and therefore may not be representative of the entire emergency physician population. These physicians may have been less likely to undergo changes in their behaviour in comparison to other physicians who were less regular or active at the hospitals. Our results may therefore not generalize to all emergency physicians. In future longitudinal studies, it is recommended that larger than required sample sizes are ensured beforehand to compensate for the various factors that may cause attrition to the pool of potential respondents.

Future Research

TPB will need to be evaluated in other implementation studies of CDRs if we are to ascertain whether it can explain and guide their uptake into clinical practice. It needs to be demonstrated whether the TPB constructs are correlated with the targeted behaviours of other CDRs. If such correlations are demonstrated, it then needs to be evaluated whether interventions can change the TPB constructs that are demonstrated to be relevant. This requires the use of prospective longitudinal studies where we can evaluate changes in the TPB constructs due to an intervention. Ideally, we would like to evaluate whether successful implementations can function through the changing of TPB constructs. Understanding the

TPB pathways through which behaviour change may occur could then better inform our design of interventions and thereby increase the uptake of CDRs.

Once we understand the active components and the pathways within which they function to change behaviour, we can study how best to facilitate behaviour change. Interventions using different implementation strategies may prove useful in altering different TPB constructs.⁸³ Some implementation strategies may therefore even be inappropriate because they change none of the constructs identified as active components in the behaviour of clinical clearance. TPB constructs may also differ in their malleability. It therefore may be easier to alter some TPB constructs rather than others. Ideally, we would like to focus on the TPB constructs which are the simplest to change or which produce the greatest change in behaviour for a given context. If the TPB constructs prove difficult to alter, other theories may have to be examined whose constructs are more open to change.

TPB has been shown to be the most useful theory in explaining the variance of behaviour for health professionals, but no individual theory can be expected to explain all behaviour.⁵² If it becomes clear that TPB does not sufficiently explain various behaviours, then factors outside of the TPB model will have to be examined. Given the inability of TPB to explain for differences in the outcomes of the C-Spine rule and CT-Head rule implementations studies, it would appear necessary to examine additional theories. This does not necessarily mean that TPB can simply be disregarded in favor of other theories but that other constructs may have to be added to compliment the existing TPB model. Work has already been performed to append additional constructs onto the TPB model so as to provide a better explanation of various behaviours, and there are even current initiatives to combine multiple theories.^{72;84} Theories may have independent sets of constructs, overlapping constructs, or even ones that are redundant. Unfortunately, theories are rarely

compared to examine which offers a better explanation of behaviour or how they may be coalesced into a unifying theory.⁸⁵ If theories are to remain relevant, they cannot remain as static entities but must change dynamically to reflect new knowledge. The TPB model may undergo many changes as we better familiarize ourselves with the pathways that explain behaviour.

It is expected that the number of CDRs will continue to grow with the current emphasis on evidence-based medicine. CDRs offer us numerous potential benefits that include simplifying the decision making process for physicians, facilitating the incorporation of new clinical research findings into practice, and standardizing the collection and interpretation of clinical data to increase the efficiency by which patients receive health care. Unfortunately, these benefits will fail to be realized if we are unable to implement CDRs into clinical practice. In addition, quality CDRs have high developmental costs that include several stages and involve thousands of patients. Given this expensive cost of development, it is not sensible to leave the implementation to chance.⁸⁶ In order to improve the process by which CDRs are implemented, we need to gain a better understanding of the factors through which behaviour change may be achieved. This analysis of TPB in the uptake of CDRs is an important first step, but only the first of many, as bettering our understanding of behaviour change will require the study and repeated testing of numerous theories.

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APPENDIX A: C-Spine TPB Survey

Scenario: Over the next year, you will see a number of alert and stable adult trauma patients who present to the emergency department on a backboard. Please answer the questions below with these patients in mind. “Clinically clearing the C-Spine” refers to establishing absence of C-Spine injury in appropriate patients by clinical examination, without use of radiography. “CCR” refers to the Canadian C-Spine Rule

A. Clinically clearing the C-Spine

1. Overall, I think that clinically clearing the C-Spine is:

Bad practice	1 2 3 4 5 6 7	Good practice
Harmful	1 2 3 4 5 6 7	Beneficial
Negative	1 2 3 4 5 6 7	Positive
The wrong thing to do	1 2 3 4 5 6 7	The right thing to do
2. I intend to clinically clear the C-Spine.

Definitely do not	1 2 3 4 5 6 7	Definitely do
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3. I want to clinically clear the C-Spine.

Definitely do not	1 2 3 4 5 6 7	Definitely do
-------------------	---------------------------	---------------
4. I plan to clinically clear the C-Spine.

Definitely do not	1 2 3 4 5 6 7	Definitely do
-------------------	---------------------------	---------------
5. My desire to clinically clear the C-Spine can be described as

No desire		Very weak		Weak		Moderate		Strong		Very strong
-----------	--	-----------	--	------	--	----------	--	--------	--	-------------
6. Most of my professional colleagues will clinically clear the C-Spine.

Definitely no	1 2 3 4 5 6 7	Definitely yes
---------------	---------------------------	----------------
7. People who are important to me think that I should clinically clear the C-Spine.

Definitely should	1 2 3 4 5 6 7	Definitely should not
-------------------	---------------------------	-----------------------
8. The Canadian Association of Emergency Physicians (CAEP) would ...

Definitely disapprove	1 2 3 4 5 6 7	Definitely approve
-----------------------	---------------------------	--------------------
- ... of my clinically clearing the C-Spine.
9. Clinically clearing the C-Spine in these patients is

Easy	1 2 3 4 5 6 7	Difficult
------	---------------------------	-----------
10. What is the likelihood that you will be able to clinically clear the C-Spine?

Very unlikely	1 2 3 4 5 6 7	Very likely
---------------	---------------------------	-------------
11. I am confident that I could clinically clear the C-Spine if I wanted to.

Strongly disagree	1 2 3 4 5 6 7	Strongly agree
-------------------	---------------------------	----------------
12. There are factors outside my control that prevent me from clinically clearing the C-Spine.

Strongly disagree	1 2 3 4 5 6 7	Strongly agree
-------------------	---------------------------	----------------
13. How much control do you have over clinically clearing the C-Spine?

No Control	1 2 3 4 5 6 7	Complete control
------------	---------------------------	------------------
14. When I am particularly busy, I am less likely to clinically clear the C-Spine.

Strongly disagree	1 2 3 4 5 6 7	Strongly agree
-------------------	---------------------------	----------------
15. My decision about whether to clinically clear the C-Spine is based on an overall clinical judgement, rather than specific consideration of individual indicators.

Strongly disagree	1 2 3 4 5 6 7	Strongly agree
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16. Please indicate which of the following apply to you in the context of clinically clearing the C-Spine (Check all that apply).

☐ I am not comfortable evaluating rotation ☐ I believe the studies and evidence supporting clearance are flawed ☐ I am too busy ; clinical clearance takes too much time and effort ☐ I see no important advantages to clinical clearance	☐ Services like Trauma and Neurosurgery will order the x-rays anyway ☐ I believe rules governing clearance are not safe for patients ☐ I resent the concept of rules and guidelines ☐ I forget the details of how to apply the rules ☐ I prefer the NEXUS Criteria to the CCR
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17. Please add any additional barriers or facilitators to clinically clearing the C-Spine at your hospital.

Barriers:

Facilitators:

18. Approximately, how many alert and stable trauma patients presenting on a backboard have you seen in the last month? ____
19. Over the last year, what percentage of alert and stable adult patients presenting on a backboard did you clinically clear the C-Spine? ____ %.
20. Please indicate how much regret you would feel after clinically clearing the C-Spine, and later finding out you had missed an important fracture
- | | | | | | | | | |
|-----------|---|---|---|---|---|---|---|---------------|
| No Regret | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strong Regret |
|-----------|---|---|---|---|---|---|---|---------------|
21. Please indicate how much regret you would feel after ordering C-Spine radiography, and later finding out you had missed an important fracture
- | | | | | | | | | |
|-----------|---|---|---|---|---|---|---|---------------|
| No Regret | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strong Regret |
|-----------|---|---|---|---|---|---|---|---------------|

B. Using the Canadian C-Spine Rule

22. Do you currently use the CCR to clinically clear the C-Spine?
Yes / No **If No, please Proceed to Section C – Professional Status**
23. Which of the following best describes the role of the CCR when you are determining whether to clinically clear the C-Spine?
- ☐ When appropriate, I make my decision primarily on the basis of the CCR
 - ☐ I make my decision on the basis of the CCR plus a small number of other key factors
 - ☐ The CCR is one of many factors I consider
 - ☐ Other _____
24. Which of the following best describes how you apply the CCR when you are determining whether to clinically clear the C-Spine?
- ☐ I apply the CCR by memory during examination of the patient
 - ☐ I apply the CCR, using memory aids when needed, during examination of the patient
 - ☐ I apply the CCR in retrospect, after examination of the patient
 - ☐ Other _____

Please complete Questions 25 – 27 WITHOUT memory aids

25. Which of the following is CONSISTENT with the CCR?
- ☐ If one high risk factor is present, examine low risk factors
 - ☐ If no high risk factor, and no low risk factor, evaluate rotation
 - ☐ If no high risk factor, and at least one low risk factor, evaluate rotation ***
 - ☐ If no high risk factor, and one low risk factor is present, No radiography
26. Which of the following is NOT considered a low risk factor in the CCR?
- | | |
|---|--|
| ☐ Sitting position in ED | ☐ Age < 65 years *** |
| ☐ Delayed onset of neck pain | ☐ Absence of midline c-spine tenderness |
| ☐ Simple rearend MVC | |
27. Which of the following is NOT considered a dangerous mechanism in the CCR?
- | | |
|--|--|
| ☐ Motorized recreational vehicles | ☐ Assault by fist, feet, blunt object *** |
| ☐ Fall from elevation (>=3 feet / 5 stairs) | ☐ Axial load to head, e.g. diving |
| ☐ Bicycle struck or collision | |

C. Professional Status

Are you: ☐ Male ☐ Female Year of birth: 19____

Year of graduation from medical school: 19____

Emergency Medicine Employment Status: ☐ Full-time ☐ Part-Time ☐ Resident

How many years have you been practicing Emergency Medicine? _____

Emergency Medicine Credentials:

☐ CCFP (EM)	☐ Dip ABEM
☐ CCFP	☐ Other, please specify _____
☐ FRCPC	

On average, how many hours per week do you devote to direct patient care in emergency medicine? ____

Thank you for your time. Please return the completed questionnaire to your study nurse.

APPENDIX B: CT-Head TPB Survey

Scenario: Over the next year, you will see a number minor head injury patients who present to the emergency department. Please answer the questions below with these patients in mind.

N.B.: “Managing patients without CT” refers to establishing absence of important head injury in appropriate minor head injury patients by clinical examination, without use of CT

A. Managing patients without CT

1. Overall, I think that managing patients without CT is:

Bad practice	1 2 3 4 5 6 7	Good practice
Harmful	1 2 3 4 5 6 7	Beneficial
Negative	1 2 3 4 5 6 7	Positive
The wrong thing to do	1 2 3 4 5 6 7	The right thing to do
2. I intend to manage patients without CT.

Definitely do not	1 2 3 4 5 6 7	Definitely do
-------------------	---------------------------	---------------
3. I want to manage patients without CT.

Definitely do not	1 2 3 4 5 6 7	Definitely do
-------------------	---------------------------	---------------
4. I plan to manage patients without CT.

Definitely do not	1 2 3 4 5 6 7	Definitely do
-------------------	---------------------------	---------------
5. My desire to manage patients without CT can be described as

No desire		Very weak		Weak		Moderate		Strong		Very strong
-----------	--	-----------	--	------	--	----------	--	--------	--	-------------
6. Most of my professional colleagues will manage patients without CT.

Definitely no	1 2 3 4 5 6 7	Definitely yes
---------------	---------------------------	----------------
7. People who are important to me think that I should manage patients without CT.

Definitely should	1 2 3 4 5 6 7	Definitely should not
-------------------	---------------------------	-----------------------
8. The Canadian Association of Emergency Physicians (CAEP) would ...

Definitely disapprove	1 2 3 4 5 6 7	Definitely approve
-----------------------	---------------------------	--------------------
9. Managing these patients without CT is

Easy	1 2 3 4 5 6 7	Difficult
------	---------------------------	-----------
10. What is the likelihood that you will be able to manage patients without CT?

Very unlikely	1 2 3 4 5 6 7	Very likely
---------------	---------------------------	-------------
11. I am confident that I could manage patients without CT if I wanted to.

Strongly disagree	1 2 3 4 5 6 7	Strongly agree
-------------------	---------------------------	----------------
12. There are factors outside my control that prevent me from managing patients without CT.

Strongly disagree	1 2 3 4 5 6 7	Strongly agree
-------------------	---------------------------	----------------
13. How much control do you have over managing patients without CT?

No control	1 2 3 4 5 6 7	Complete control
------------	---------------------------	------------------
14. When I am particularly busy, I am less likely to manage patients without CT.

Strongly disagree	1 2 3 4 5 6 7	Strongly agree
-------------------	---------------------------	----------------
15. My decision about whether to manage patients without CT is based on an overall clinical judgement, rather than specific consideration of individual indicators.

Strongly disagree	1 2 3 4 5 6 7	Strongly agree
-------------------	---------------------------	----------------
16. Please indicate which of the following apply to you in the context of managing patients without CT (Check all that apply).

☐ I believe the studies and evidence supporting managing without CT are flawed ☐ I am too busy; managing without CT takes too much time and effort ☐ I see no important advantages to managing without CT ☐ Services like Trauma and Neurosurgery will order the CT anyway	☐ I believe rules governing management without CT are not safe for patients ☐ I resent the concept of rules and guidelines ☐ I forget the details of how to apply the rules
---	--

17. Please add any additional barriers or facilitators to managing patients without CT at your hospital.

Barriers:

Facilitators:

18. Approximately, how many patients with minor head injury have you seen in the last month? _____
19. Over the last year, what percentage of patients with minor head injury did you manage without CT? _____%
20. Please indicate how much regret you would feel after managing a patient without CT, and later finding out you had missed an important injury
- | | | | | | | | | |
|-----------|---|---|---|---|---|---|---|---------------|
| No regret | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strong regret |
|-----------|---|---|---|---|---|---|---|---------------|
21. Please indicate how much regret you would feel after ordering a CT, and later finding out you had missed an important injury
- | | | | | | | | | |
|-----------|---|---|---|---|---|---|---|---------------|
| No regret | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strong regret |
|-----------|---|---|---|---|---|---|---|---------------|

B. Using the Canadian CT Head Rule

22. Do you currently use the Canadian CT Head Rule to manage patients without CT? Yes / No **If No, please Proceed to Section C – Professional Status**
23. Which of the following best describes the role of the Canadian CT Head Rule when you are determining whether to manage a patient without CT?
- ☐ When appropriate, I make my decision primarily on the basis of the Canadian CT Head Rule
 - ☐ I make my decision on the basis of the Canadian CT Head Rule plus a small number of other key factors
 - ☐ The Canadian CT Head Rule is one of many factors I consider
 - ☐ Other _____
24. Which of the following best describes how you apply the Canadian CT Head Rule when determining whether to manage a patient without CT?
- ☐ I apply the Canadian CT Head Rule by memory during examination of the patient
 - ☐ I apply the Canadian CT Head Rule, using memory aids when needed, during examination of the patient
 - ☐ I apply the Canadian CT Head Rule in retrospect, after examination of the patient
 - ☐ Other _____

Please complete Questions 25 – 26 WITHOUT memory aids

25. Which of the following is NOT considered a high risk factor in the Canadian CT Head Rule?
- ☐ Suspected open or depressed skull fracture
 - ☐ Seizure
 - ☐ More than two episodes of vomiting
 - ☐ Age $\geq$ 65 years
 - ☐ GCS score $<$ 15 at 2 hours after injury
26. Which of the following is NOT considered a dangerous mechanism in the Canadian CT Head Rule?
- ☐ Fall from elevation ($\geq$ 3 feet / 5 stairs)
 - ☐ Ejection from motor vehicle
 - ☐ Pedestrian struck by vehicle
 - ☐ Motorized recreational vehicle

C. Professional Status

Are you: ☐ Male ☐ Female Year of birth: 19____

Year of graduation from medical school: 19____

Emergency Medicine Employment Status: ☐ Full-Time ☐ Part-Time ☐ Resident

How many years have you been practicing Emergency Medicine? _____

Emergency Medicine Credentials:

- ☐ CCFP (EM)
- ☐ CCFP
- ☐ FRCPC
- ☐ Dip ABEM
- ☐ Other, please specify _____

On average, how many hours per week do you devote to direct patient care in emergency medicine? _____

Thank you for your time. Please return the completed questionnaire to your study nurse.

APPENDIX C: Relevant Variables Collected through Implementation Studies

Variable	Description
Patient ID	Unique Identification Number for Patient
Physician ID	Unique Identification Number of Physician who treated Patient
Hospital ID	Identification Number of Hospital where patient was treated
Group	Dichotomous Variable that indicates Group Assignment (Intervention/Control) for Hospital where patient was treated
Phase	Dichotomous Variables that indicates whether patient was treated in pre-phase or post-phase
Arrival by Ambulance	Dichotomous Variables that indicates whether patient arrived by ambulance or by their own means
Admission to Hospital	Dichotomous Variables that indicates whether patient was subsequently admitted to the hospital or released
Radiography	Dichotomous Variable that indicates whether the patient being treated underwent radiography