

FOCUS ON TOMORROW

RESEARCH FUNDED BY WORKSAFEBC

Development of an Ergonomic Syringe Adapter

October 2011

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RS2010-IG14



WORKING TO MAKE A DIFFERENCE

Development of an Ergonomic Syringe Adapter

**This research is supported with funds from
WorkSafeBC through the FOCUS ON TOMORROW program**

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Date: October 2011

MAIN RESEARCH/PROJECT FINDINGS:

- Ergonomic syringe adapter developed for IV chemotherapy drug administration, was shown to minimize risk of injury to the hand, wrist, and elbow by:
 - Significantly reducing hand-grip force by a factor of 2.2:1 ($p<0.01$)
 - Hand-grip force distributed over entire hand and fingers, rather than 2 finger tips and thumb tip
 - Eliminating awkward hand and wrist postures
- 10 out of 10 Chemotherapy nurses in the BC Cancer Agency who evaluated the adapter stated that they would use the adapter if it was available to them
- 8 out of 10 nurses indicated that they would use the adapter instead of a standard syringe
- On the average, the nurses in the evaluation study who had pain in the thumb, hand, wrist, or forearm (8 out of 10 nurses) stated that they experienced less pain when using the adapter as compared to only using a syringe
- On the average, the nurses in the evaluation study found the adapter to be more comfortable than using a syringe
- The adapter is designed to be:
 - Quick and easy to set up
 - Easy to use
 - Used with either hand
 - Safe for patient and nurse
 - Easy to clean with some components being disposable
 - Low cost
 - Universal in that it will fit a variety of the larger syringe sizes from the 3 main syringe manufacturers: Monojet, BD, and Terumo.

WORKPLACE HEALTH AND SAFETY IMPLICATIONS:

- Use of adapter for IV chemotherapy drug administration will result in a significant reduction in risk for injury to the hand, wrist, forearm, and elbow
- Nurses who are currently working in pain will likely be able to work in more comfort, with quicker recovery from injury
- Global implications as this type of chemotherapy treatment is performed in chemotherapy clinics globally; market research shows that there are approximately 2.5 million visits annually in North America for cancer therapy treatment using IV drug administration
- A modified version of the adapter may be of benefit to Pharmacy Technicians who are responsible for pre-filling syringes manually, and therefore at risk for MSI; a prototype of this device is currently being constructed.

EXECUTIVE SUMMARY

An ergonomic syringe adapter has been designed to eliminate awkward hand and wrist postures, and significantly reduce hand grip force that is encountered during IV chemotherapy drug administration, so that risk of injury to Chemotherapy nurses is reduced to an acceptable level. Currently, there is no other adapter on the market that can be used to reduce risk of injury during IV chemotherapy drug administration. The British Columbia Institute of Technology (BCIT) Products and Process Applied Research Team was contracted under a grant from WorkSafeBC to develop the adapter over the following 5 phases:

1. Development of design requirements - the design requirements were identified over a series of discussions and feedback from the potential users of the device. Additionally, 4 nurses from the Vancouver Cancer Centre (VCC) were videotaped during a mock procedure to gather information for the design requirements. A hazard analysis was conducted to determine safety and regulatory requirements, which were incorporated into the overall design requirements.
2. Concept development – a Gap analysis was used in which the design requirements were compared to the existing concept to determine modifications required to meet the requirements. The adapter was then modified and 2 versions of the prototype were evaluated by 4 nurses from VCC and 6 nurses from the Abbotsford Cancer Centre to get feedback on usability, functionality, ergonomics, and safety. Based on the feedback from the end-users, a final version of the adapter was chosen that best met the design requirements.

3. Detailed design - The purpose of this phase was to create design drawings suitable for the fabrication of a proof-of-concept prototype.
4. Device fabrication - The purpose of this phase was to fabricate a “proof of principle” system that is designed to meet the requirements and can be used in the verification and validation process. A meeting with the Infection Control department at VCC was held to ensure that the new prototype satisfied their requirements. A search of existing patents revealed that the syringe adapter design was unique, and therefore a US provisional patent application was filed prior to the evaluation trial being conducted.
5. Device verification and validation - The purpose of this phase was to verify the adapter against the design requirements to ensure it met those requirements. This phase was conducted using design team consensus in combination with a research study performed at the BCIT Human Motion Laboratory. During the study, ten subjects (10 female Chemotherapy nurses) were evaluated with and without the adapter to determine the effectiveness of the adapter at reducing hand-grip force and minimizing awkward hand and wrist postures. Force sensors and electrogoniometers (angle sensors) were used to determine hand-grip force and joint angles, respectively. A questionnaire was also administered to the subjects to get feedback on usability, functionality, ergonomics, safety, hygiene, and aesthetics.

Results of the study showed that hand-grip force was reduced by a factor of more than 2 to 1 over that encountered with a standard syringe, and awkward hand and wrist postures were eliminated. Additionally, the adapter allows for right or left-handed use, to allow for alternation of hands within and between patients to minimize risk of muscle

fatigue. All 10 subjects in the study stated that they would use the adapter if it was available to them, with 8 out of 10 stating that they would use the adapter exclusively. The adapter consists of 4 components and is designed to be low cost with both disposable and reusable components. It is also designed to be universal in that it will accommodate a variety of different size syringes from the 3 main syringe manufacturers in North America: Monojet, BD, and Terumo. The Technology Development Office within the BCCA is funding marketing of the adapter, which is now underway.

Key Words: syringe, adapter, hand, wrist, injury, chemotherapy, nurse

RESEARCH/PROJECT PROBLEM AND CONTEXT

Many cancer patients cannot receive chemotherapy drugs via syringe pump. As a result, nurses must administer the medication manually with large volume syringes. An ergonomic assessment conducted by a PHSA Ergonomist revealed that there is a moderate-to-high risk of injury to the hand, wrist, forearm, and elbow of British Columbia Cancer Agency (BCCA) nurses who administer chemotherapy drugs via large volume syringes (20 cc and greater) as a result of prolonged static and awkward hand and wrist postures combined with hand-grip force.

As part of the ergonomic assessment, a pain/discomfort survey was distributed to all Chemotherapy Nurses in the BCCA to assist with the determination of risk factors and potential solutions. There were a total of 54 respondents. Results of the survey revealed the following:

- **Question 6:** The body parts most affected were the hand/fingers (15 out of 29 respondents = 52%), wrist (14 out of 25 respondents = 52%), and forearm (9 out of 24 respondents = 37.5%).
- **Question 11:** 16 out of 35 individuals reported that administration of chemotherapy drugs via syringe was a causative factor.
- **Question 16:** the average level of pain or discomfort was rated as 3 out of 10 (0 = no pain, 10 = unbearable)
- **Question 22:** It was reported that an average of 10 to 15 syringes were used per shift.
- **Question 24:** The majority of respondents (23 out of 36 = 64%) indicated that 20 ml and greater volume syringes were the most problematic.

- **Question 27:** 36 respondents indicated that, on the average, they spend approximately 23% of their work shift administering chemotherapy drugs via syringe.

Additionally, injury stats for Chemo Nurses in the BCCA were reviewed for a 2-year period between Jan/06 and Dec/07 to determine the body parts affected and potential causative factors. Out of 19 injury reports, 16 nurses reported that the causative factor was administration of chemo drugs via syringe. In all 19 cases, pain and discomfort was localized to the hand, wrist, and forearm.

In response to this problem, a PHSA Ergonomist and a Biomedical Engineer at Children's and Women's Health Centre designed an ergonomic syringe adapter that can be used to reduce the risk of injury by reducing hand-grip force and eliminating awkward hand and wrist postures. The Biomedical Engineer constructed a prototype of the device so that proof-of-concept could be demonstrated to end-users. Subsequent meetings with end-users revealed that there was interest in pursuing further development of the adapter. The Technology Development Office (TDO) at the BCCA was approached for assistance with funding for further development of the adapter. The TDO agreed to fund patenting and marketing of the device; however, their office does not fund further development of products. As a result, an application was submitted for the Innovation at Work grant provided through the Research Secretariat at WorkSafeBC. Funding through this grant was approved for further development of the adapter with the assistance of the BCIT Products and Process Applied Research Team.

METHODOLOGY

Further development of the adapter took place over the following 5 phases (see report prepared by BCIT for further details on each phase):

1. Development of design requirements - the design requirements (see Appendix 1 of BCIT report) were identified over a series of discussions and feedback from the potential users of the device. Additionally, 4 nurses from the Vancouver Cancer Centre (VCC) were videotaped during a mock procedure to gather information for the design requirements. A hazard analysis (see Appendix 2 of BCIT report) was conducted to determine safety and regulatory requirements, which were incorporated into the overall design requirements.
2. Concept development (see pages 9 to 11 of BCIT report for more details) – a Gap analysis was used in which the design requirements were compared to the existing concept to determine modifications required to meet the requirements. The main issues identified with the original prototype were: 1) large size of the adapter and, 2) assembly time required to install the syringe in the adapter. To overcome these deficiencies, two main concepts were brainstormed. The first concept utilized the same mechanical motion of drug delivery as the current process, namely, the syringe barrel is held stationary and the plunger is moved forward (away from the nurse). In the second concept, the plunger is held stationary and the barrel of the syringe is pulled backwards (toward the nurse) to inject the drug. This was the same motion as the original prototype, although the intention was to scale down the size significantly. Based on these concepts, 2 versions of the adapter were constructed and evaluated by 4 nurses from VCC and 6 nurses from the Abbotsford Cancer Centre to get

feedback on usability, functionality, ergonomics, and safety. Based on the feedback from the end-users, a final version of the adapter was chosen that best met the design requirements.

3. Detailed design (see pages 10 to 14 of BCIT report for more details) - The purpose of this phase was to create design drawings suitable for the fabrication of one proof-of-concept prototype.
4. Device fabrication (see page 15 of BCIT report for more details) - The purpose of this phase was to fabricate a “proof of principle” system that is designed to meet the requirements and can be used in the verification and validation process. A meeting with the Infection Control department at VCC was held to ensure that the new prototype satisfied their requirements.
5. Device verification and validation (see pages 15 & 16 of BCIT report, and Appendices 3 & 4 for more details) - The purpose of this phase was to verify the adapter against the design requirements to ensure it met those requirements. This phase was conducted using design team consensus in combination with a study performed at the BCIT Human Motion Laboratory. During the study, ten subjects (10 female Chemotherapy nurses) were evaluated with and without the adapter to determine the effectiveness of the adapter at reducing hand-grip force and minimizing awkward hand and wrist postures. Force sensors and electrogoniometers (angle sensors) were used to determine hand-grip force and joint angles, respectively. A questionnaire was also administered to the subjects to obtain feedback on usability, functionality, ergonomics, safety, hygiene, and aesthetics.

Subjects

Subjects included 10 female Chemotherapy nurses from the Vancouver and Abbotsford Cancer Centers who responded to a recruitment poster for the evaluation (see Appendix 3 of BCIT report). Subjects were excluded from participating if they were on leave or limited duties due to an injury. Six nurses from the Vancouver Center and four from the Abbotsford Center were chosen to participate in the evaluation, for a total of 10 subjects. Subjects were asked to read and sign an Informed Consent form (see Appendix 3 of BCIT report) prior to participating in the evaluation. The average age of the subjects was 42 ± 11.5 years, and their average number of years experience working as a Chemotherapy nurse was 7.9.

Methods

Testing for the evaluation took place in the BCIT Motion Capture Lab, located in the Centre for Applied Research and Innovation at the Burnaby campus. The evaluation was conducted by members of the BCIT Technology Product Evaluation Group. Ethics approval for the evaluation was obtained from the BCIT Research Ethics Board (REB).

The test setting consisted of a mock “patient” who was seated in a patient treatment chair, identical to the chairs used within the BCCA (Figure 1). No real drugs were used for the evaluation; instead, saline was injected into flexible tubing that was affixed to the arm of the “patient” at locations along the patient’s hand and arm that simulated actual IV drug injection locations. The resistive fluid pressure in the syringe and tubing was adjusted with a regulator and held constant at 0.8 kg so that it mimicked the pressure

normally experienced during Chemo drug administration, and all fluids drained into a nearby receptacle.

Subjects were seated on a height adjustable task chair or stool, and asked to adjust the height of the chair/stool to assume a body posture that felt most comfortable to them. The testers ensured that the height and position of the chair/stool did not result in any awkward body postures. Subjects were given a demonstration of the syringe adapter prior to testing, and asked to set up the adapter as part of the test trial. Subjects were each allowed one practice trial for each method prior to testing. All trials were performed on the right-hand side of the patient, due to difficulty in moving measurement equipment between sides of the chair.



Figure 1. Evaluation set-up

The evaluation consisted of a comparison between the syringe adapter and a standard syringe that is used for delivery of IV chemotherapy drugs. Factors that were measured and compared included: 1) hand-grip force, 2) thumb flexion/extension, 3) finger flexion/extension, 4) wrist flexion/extension 5) wrist ulnar/radial deviation, 6) elbow flexion, 7) shoulder abduction, and 8) shoulder flexion/extension.

Subjects were asked to perform the task of “medication delivery” by depressing the plunger of the syringe until 2 ml of fluid had been dispensed, at which point they were asked to perform a “blood return check” by pinching off the line with their opposite hand, followed by an additional 2 ml of fluid being dispensed, at which point data collection was terminated. Subjects from the Abbotsford Cancer Center used a 35 ml syringe, to be consistent with their standard clinical practice, whereas subjects from the Vancouver Cancer Center used a 60 ml syringe, to be consistent with their standard clinical practice. At the start of the procedure, the syringe was filled to 50% of the total volume of the syringe, to be consistent with clinical practice. All subjects performed the task with a standard syringe first, followed by the syringe adapter. Due to the short duration of the task (average time = 2 minutes), followed by a recovery period of 5 minutes, muscle fatigue was not a factor, so task randomization was not required.

Force sensors (Tekscan A201 Flexiforce 0-25lb flexiforce sensors) were applied to the syringe at the end of the plunger and on both sides of the flange for the standard syringe method (Figure 2), and in between the hand-grip adapter and the barrel of the syringe for the syringe adapter method (Figure 3), so that 3 sensors in total were used for each method. The maximum force for each sensor was recorded, with the maximum force for all 3 sensors was used for comparison purposes between the 2 methods of drug administration. Student’s paired T-test was used to determine statistical significance between methods. The Borg CR10 scale for estimating grip forces was used as a back-up measurement system in case there were any issues identified with the force sensor data.

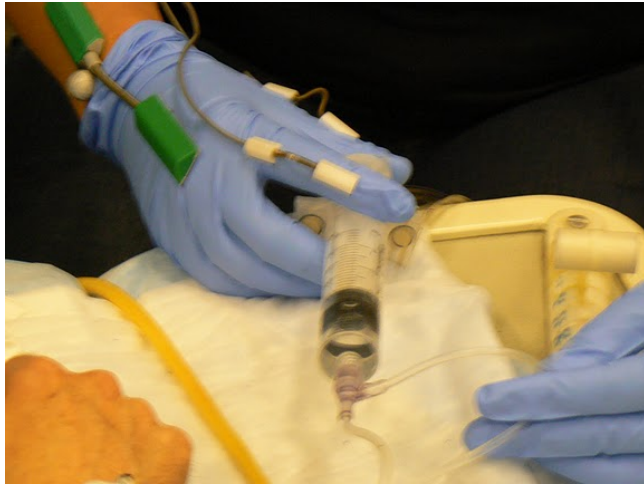


Figure 2. Force sensors on standard syringe Figure 3. Force sensors on adapter

Electrogoniometers were used for joint angle measurements on the thumb/ index finger (Biometrics F35 Single axis goniometers), and wrist joint (Biometrics SG65 twin axis goniometer) (Figure 4), while the ErgoMaster ergonomics analyzer was used to calculate elbow and shoulder joint angles from sagittal and frontal plane still images of relevant joint markers (Figure 5). Peak joint angles were recorded for each subject and used for comparison purposes between the 2 methods of drug administration. Student's paired T-test was used to determine statistical significance between methods.

All sensor data was captured with Biometrics DataLOG software.

After performing the test trials, each subject was asked to complete a questionnaire (see Appendix 4 of BCIT report) regarding the usability of the device.



Figure 4. Electrogoniometers



Figure 5. Joint markers

RESEARCH/PROJECT FINDINGS (see pages 16 & 17 of BCIT report and Appendix 5)

Hand-grip force

The average maximum hand-grip force recorded from all sensors was found to be significantly higher for the standard syringe as compared to the syringe adapter ($p < 0.01$). The force ratio between the standard syringe and the syringe adapter was found to be 2.2:1.

The average Borg CR10 scale force was found to be significantly higher for the standard syringe as compared to the syringe adapter ($p < 0.01$). The force ratio between the standard syringe and the syringe adapter was found to be 1.8:1.

Table 1. Hand-grip force results

Parameter	Standard syringe	Syringe adapter	Ratio (standard/adapter)
Max force (all sensors) (kg) (\pm SD)	1.21 \pm 0.77**	0.56 \pm 0.50	2.2:1
Borg CR10 scale (\pm SD)	3.3 \pm 1.24**	1.8 \pm 0.94	1.8:1

** $p < 0.01$

Joint angles

There was significantly more wrist flexion for the standard syringe as compared to the syringe adapter ($p < 0.01$), with the syringe adapter resulting in a near-optimal wrist posture (3.25 degrees of extension). There was significantly more shoulder extension for the syringe adapter as compared to the standard syringe ($p < 0.05$). Although not statistically significant, there was approximately 10 degrees less thumb extension for the syringe adapter as compared to the standard syringe ($p = 0.08$). Although not statistically significant, there was approximately 8 degrees less radial deviation of the wrist with the syringe adapter as compared to the standard syringe ($p = 0.13$). There was no significant difference in shoulder abduction between the 2 methods.

Table 2. Joint angles

Parameter	Standard syringe	Syringe adapter
Thumb Flexion (deg) (\pm SD)	9.32 \pm 10.48	8.73 \pm 7.76
Thumb Extension (deg) (\pm SD)	-17.78 \pm 13.37	-7.63 \pm 7.54
Finger Flexion (deg) (\pm SD)	46.35 \pm 25.75	49.00 \pm 11.88
Finger Extension (deg) (\pm SD)	9.21 \pm 11.92	15.17 \pm 11.75
Wrist Flexion (deg) (\pm SD)	13.78 \pm 10.77**	-3.25 \pm 14.00
Wrist Extension (deg) (\pm SD)	-37.64 \pm 16.86	-33.49 \pm 10.72
Wrist Radial deviation (deg) (\pm SD)	14.16 \pm 10.04	6.17 \pm 9.43
Wrist Ulnar deviation (deg) (\pm SD)	-20.31 \pm 12.21	-17.44 \pm 12.39
Elbow Flexion (deg) (\pm SD)	81.40 \pm 12.96	90.10 \pm 9.39
Shoulder Abduction (deg) (\pm SD)	15.10 \pm 3.81	15.40 \pm 10.16
Shoulder Extension (deg) (\pm SD)	8.00 \pm 18.27	21.80 \pm 16.83*

** p <0.01 * p <0.05

Questionnaire Results

- 10 out of 10 Chemotherapy nurses in the BC Cancer Agency who evaluated the adapter indicated that they would use the adapter if it was available to them. 8 out of the 10 nurses indicated that they would use the adapter exclusively.
- On the average, the subjects who had pain in the thumb, hand, wrist, or forearm (8 out of 10 nurses) indicated that they experienced less pain when using the adapter as compared to using a standard syringe.
- On the average, the subjects found the adapter to be more comfortable than using a standard syringe

Design Features

The adapter is designed to be:

- Quick and easy to set up
- Easy to use
- Used with either hand
- Safe for patient and nurse
- Easy to clean with some components being disposable
- Low cost

The adapter consists of the following 4 components (see SolidWorks file): 1) mounting platform (page 4), 2) swivel arm (page 5), 3) plunger mounting bracket (page 6), and 4) hand-grip adapter (page 7). The plunger mounting bracket and hand-grip adapter are designed to be disposable due to the difficulty in cleaning these components, while the mounting platform and swivel arm are designed to be more permanent in nature, due to

the ease of cleaning. The mounting platform, swivel arm, and plunger mounting bracket can be manufactured from a high-strength plastic, while the hand-grip adapter can be manufactured from a compressible material such as polyurethane, to allow it to conform to the shape of the user's hand. It was discovered that the thickness of the patient arm trays varied by 0.25 cm, and therefore a universal mounting platform was developed. The complete assembly of the adapter is shown on pages 1 to 3 of the SolidWorks file, and in Figure 6 below. The adapter mounting system is shown in Figure 7 below.

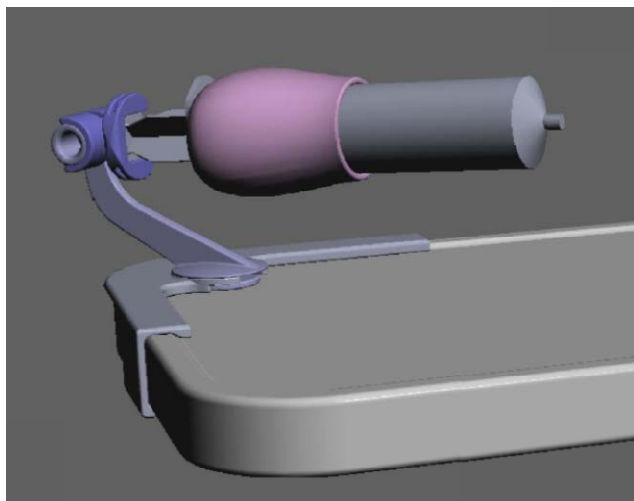


Figure 6. Syringe adapter

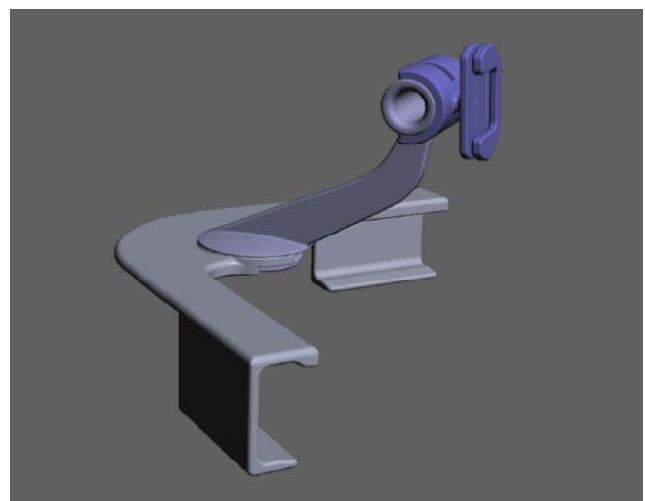


Figure 7. Adapter mounting system

Discussion of Results

Maximum hand-grip forces were found to be significantly lower when using the syringe adapter as compared to a standard syringe by a factor of 2.2:1. Subjective hand-grip force measurements showed that the subjects, on the average, found a standard syringe to be “moderate to somewhat hard” in comparison to the syringe adapter, which they found “very light to fairly light. In addition to the reduction in hand-grip force, the hand-grip forces are distributed over the entire hand and fingers when using the

adapter, rather than 2 finger tips and the thumb tip as when using a standard syringe, which further reduces stress across joints of the hand and wrist of the user.

The adapter resulted in an elimination of awkward wrist flexion, with near-optimal wrist posture. There was approximately 10 degrees less thumb extension when using the syringe adapter as compared to a standard syringe, with the result being a near-neutral (i.e. power grip) hand posture.

The adapter resulted in a significantly greater amount of shoulder extension as compared to a standard syringe, due to the pulling motion required for operation of the adapter. While the maximum amount of shoulder extension is not considered excessive, this may provide important information for training nurses on the use of the adapter, in that a slight amount of shoulder flexion at the start of the procedure would be beneficial to help avoid extended shoulder postures.

There was no difference in shoulder abduction between the syringe adapter and a standard syringe, with the amount of shoulder abduction being within a neutral range.

The high percentage of acceptance of the syringe adapter as an alternative to using a standard syringe indicates that there would be minimal resistance from nurses if the adapter were to be commercially available.

Implications for Future Research/Projects on Workplace Health and Safety

The methods used in this project to develop and evaluate a new ergonomic product for use in healthcare could be used in the development and evaluation of other ergonomic products in the healthcare field.

Immediate and Long-Term Benefits of the Findings

- Immediate benefits of the findings present a solution to the moderate-to-high risk of injury associated with IV chemotherapy drug administration, which will help to alleviate the ongoing psychological stress experienced by Chemotherapy nurses, who have been limited until now in terms of devices that can be used to reduce their risk of injury to an acceptable level.
- Long-term benefits include a significant reduction in risk for injury, which will likely result in a reduction in frequency and severity of injuries.

Relevant User Groups for the Research/Project Results

- BC Nurses' Union
- BCCA Chemotherapy nurses
- OHS Connect
- WSBC
- Healthcare Safety Professional Association of BC (HCSPABC)

Dissemination/Knowledge Transfer

Results of the research project will be disseminated to the BC Nurses' Union, OHS Connect within the PHSA, and WSBC so that the information regarding the adapter can be disseminated to nursing staff throughout the province.

The Workplace Health department in the PHSA will develop a safe work procedure for use of the adapter in poster and video format, and will provide training sessions to all Chemotherapy nursing staff in the PHSA.

The results of the project will also be detailed in a scientific paper for publication in a reputable nursing journal, so that the results can be disseminated on a more global scale.

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