ORIGINAL ARTICLE

# Innovation in tools for safe manual handling in a Hong Kong private hospital

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## ABSTRACT

Staff in the healthcare industry are susceptible to musculoskeletal injuries due to frequent manual handling procedures. The study describes the systematic approach in proactive risk assessment of occupational safety and innovative design of appropriate tools to minimise the risk of injury to staff in a private hospital in Hong Kong. As a result, 4 tools to cater to specific manual handling procedures were developed by an in-house engineering team. The study highlights the benefits of incorporating innovations in tool (re)design to enhance safe manual handling in a hospital setting.

## INTRODUCTION

Management of musculoskeletal disorders and back injuries associated with manual (and patient) handling among healthcare workers has long been a challenge in the healthcare industry worldwide.[1] Healthcare workers were found to have the highest rate of musculoskeletal disorders among all industries in the USA[2] and had seven times the average rate of musculoskeletal disorders at the national level.[3] In Hong Kong, there were over 1600 occupational injuries in the healthcare sector reported in 2013, of which one-third were injuries related to manual handling operations.[4]

The cumulative effect ranging from excessive movement and repetitive stress to wrists, hands and back when lifting loads and handling patients resulted in persistent pain and posed adverse impact on quality of life of the injured workers.[5 6] Global initiatives to tackle the problem generally included delineation of Occupational Safety and Health (OSH) standards and provision of comprehensive training programmes. While OSH standards have become mature and are widely adopted all over or in most parts of the world, the effectiveness of training programmes specifically on safety outcomes required further investigation.[7–9] Recently, the National Institute for OSH (NIOSH) of the Centre for Disease Control (CDC) of the USA has launched an initiative to promulgate the ideas of preventing occupational injuries through better and innovative design of tools, equipment and workflow.[10]

In concert with several studies demonstrating local intelligence in innovative design of equipment in preventing musculoskeletal injuries,[11 12] a descriptive study was conducted in Union Hospital, a private hospital with over 400 beds and 1600 staff in Hong Kong. This study aimed to highlight the approach in handling specific occupational risks in a local context from 2012 to 2014 through the design of four innovative tools, namely, roller transfer plate (RTP), operating table footboard trolley (OTFT), gas cylinder transfer system (GCTS) and carton box opening tool (CBOT).

## METHOD

OSH issues are one of the safety priorities in the hospital. Regular meetings with the hospital management and a reporting system for staff to reflect OSH concerns are in place. A strategic planning model for OSH issues has been established to ensure that concerns from staff were addressed.

### Staff awareness

All Safety Alerts (potential risk on working environment or procedure) and injury-on-duty (IOD) incidents reported by staff would be reviewed by the OSH committee, which is composed of various professionals including doctors, nurses, engineers, physiotherapists and safety officers. Committee members would review and investigate the OSH concerns from staff and conduct a site investigation when necessary.

### Site investigation and problem identification

During the site investigation, the estate department would confirm the details of request from staff and explore the operational feasibility and carry out risk assessment before adopting the engineering approach. During the process of developing solutions, comments from users and committee members would be sought.

### Design engineering

When redesigning of equipment is necessary, human factors would be considered and integrated into the design of tools according to the following principles:[13]

1. The tools were designed with reference to the ergonomic standards as advised by the physiotherapist.
2. Users were actively involved in the planning and development process.
3. Users' characteristics were considered including gender, strength and body size.
4. Proper interfacing among the users, the tools and the existing operation process/system was ascertained.
5. Simple, easy and safe to use.

### Field testing of tools

Supplemented with self-explained sketches, preliminary design of tools would be examined by users by conducting an onsite test which includes:

1. Site measurement involving users for their comments.
2. Provision of a prototype made of a carton box/wooden materials.
3. Functional test of a prototype prior to making the actual tools.
4. Discussion with end user and frontline staff.

### Production of real tools

After the onsite test, the actual tools would be produced by the engineers of the estate department. Repeated testing and modifications would be conducted during the user acceptance test period. Tools would then be put forward for trial.

### Official launch of tools

After the trial period, the finalised tools would be formally introduced to staff after endorsement from the hospital management.

Training would be provided to staff on the proper use of the new tools. Regular evaluations from users would be conducted to ascertain the effectiveness and applicability of the tools. Results from evaluations would be reported to the OSH committee for discussion on plausible enhancements or modification of tools and the relevant benefits in minimising the risk of injuries.

## RESULTS

During 2012–2015, the OSH committee identified the heightening risk in manual handling in several areas and therefore recommended that specific tools be modified to prevent possible injury. As a result, four tools were developed in relation to manual handling operations by the engineering team of the estate department. Properties of tools are summarised in table 1.

**Table 1** Summary of the tools' characteristics and statistics

| | Roller transfer plate (RTP) | Operating table footboard trolley (OTFT) | Carton box opening tool (CBOT) | Gas cylinder transfer system (GCTS) |
|---|---|---|---|---|
| Scope of application | Manual lifting of patient in taxi or private car | Lift and hold the leg section of operating table | Pull open carton box with bare hand | Drag out heavy cylinder from the bottom of storage rack |
| Dimension (mm) | | | | |
| Length | 1530 | 500 | 225 | 1040 |
| Width | 350 | 640 | 120 | 250 |
| Height | 1100 | 590 | 40 | 220 |
| Year of introduction | November 2012 | May 2012 | July 2013 | March 2015 |
| Frequency of usage | | | | |
| Estimated times of usage | 3/year | At least 1560/year | 7800/year | 730/year |
| Compliance rate | 100% | 100% | 100% | 100% |
| Number of injury-on-duty | | | | |
| Before tools introduced | 2 | 0 | 2 | 0 |
| After tools introduced | 0 | 0 | 0 | 0 |
| Cost (HKD) *US$1=HKD 7.8 | | | | |
| Material cost | HKD 4000 | HKD 1600 | HKD 300 | HKD 1800 |
| Labour cost (covered by in-house engineering team) | HKD 4000 | HKD 1600 | HKD 600 | HKD 2000 |
| Total cost | HKD 8000 | HKD 3200 | HKD 900 | HKD 3800 |

*Hong Kong Monetary Authoity - The linked exchange rate system. http://www.hkma.gov.hk/moneyhk/eng/monetary/linkede.htm (accessed Aug 2016).



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#### Roller transfer plate (RTP)

A majority of patients arrive at Union Hospital by taxi and private cars as public ambulance services in Hong Kong do not transport patients to private hospitals. Some of the patients may be debilitated or of limited mobility such as pregnant women under intense labour pain. In the past, they would be manually lifted and transferred out from the vehicle by at least two staff members. Owing to the limited space in the passenger compartment, two staff members had to lift the patient in a contorted posture. As a result, staff often reported back pain and stress when moving patients out of the vehicle. During 2011–2012, there were two cases of injury related to moving patients in a confined space, affecting 8% of nursing staff in that department.

Investigation by our OSH committee indicated that the lateral transfer of patients in a confined space would restrict proper lifting posture and greater lifting effort is required, which may lead to back and waist injuries. After extensive research through suppliers, patents, journals, public and private hospitals, engineering associations and internet resources, no readily available tools that reduce risk of injury from lifting or transferring patients from the confined space of a vehicle/taxi to a wheelchair/stretcher could be found.

A RTP was therefore invented (figure 1). A patient would be placed on the roller part of the RTP, which consisted of rollers with bearings to help slide the patient towards the rear end of the trolley. A thick cloth would be placed underneath the patient or on the trolley to increase the patient's comfort. On reaching the rear end, the patient could either sit up with back support, or continue to lie down, after which the RTP could be manoeuvred to a spacious environment so that the patient could be laterally transferred from the RTP to the stretcher by staff without space restriction (figure 2). There was no need for staff to manually lift the patient within the confined space in the vehicle.

#### Operating table footboard trolley (OTFT)

Operating tables which are used in most surgical procedures consist of several sections, including the leg section. For some procedures such as haemorrhoidectomy, the leg section has to be removed so that the patient can be placed in a lithotomy position. The leg section may need to be removed and reinstalled several times during the operation to adjust the patient's position for surgery. Strains, back pain, joint and muscle aches were reported by staff as they had to repetitively lift and hold the leg section which weighed around 138 N. According to the torque equation (1) and assuming spinal cord is the pivot, torque experiences by the hands is equaled to torque experiences by the back. Staff would have to experience 1380 N (138 N×500/50)'s force at his/her back to uplift the leg section. There are two more assumptions: he/she is required to extend his/her arm to 500 mm to hold the footboard while the distance between his/her back and spinal cord is assumed to be 50 mm.

$$(\text{Torque (r)} = \text{length (l)} \times \text{force (F)})$$

An OTFT was therefore designed with a soft pad and a trolley (figure 3). The leg section was secured on the trolley which was of the same height as the operating table. The two metal bars connecting the footboard and the operating table need to be individually adjusted to fit in the mounting holes of the leg section and may not align to the hole of the operating table (figure 3).


**Figure 1** The roller transfer plate. (A) The roller bearings on the platform are designed for easy sliding of patients. (B) Soft pad was added at the end of trolley to reduce the risk of injury. (C) The height of the trolley matches the height of the average seat to facilitate easy transfer of patients. (D) The frontal part of the trolley was a smooth ramp, which enabled patients to be moved onto the RTP with the least effort.


**Figure 2** The process of using the roller transfer plate. (A) The RTP was being moved into the car. (B) A thick cloth was placed underneath the patient. (C) The roller bearings helped sliding the patient towards the rear end of the RTP. (D) Patient was transferred from the RTP to a stretcher with a market available Patslide.


**Figure 3** The operating table footboard trolley (OTFT) and its operation before and after the introduction of tool. (A) OTFT was designed by placing a soft pad on a trolley which was at the same height of the operating table. The soft pad was engrained to provide flexibility of slight angle adjustment during the insertion of the leg section into the operating table. The soft pad was an economical and environmental friendly accessory as it was excised from an old, not-in-use operating table. (B) Manual handling of leg section before the OTFT was introduced. (C) OTFT can be operated easily by placing it under the leg section, which should be placed horizontally to the operating table. (D) The two metal bars connecting the footboard and the operating table did not align with the hole of the operating table.

Even if the operating table is adjusted to the height of the trolley, the leg section may not plug into the operating table by just pushing the trolley forward. The soft padding on the OTFT provides the flexibility of slight angle adjustment for the users to insert these metal bars and enhances the smooth insertion of the footboard into the operating table. Lifting force was completely eliminated and potential manual handling risk was eliminated after this installation, as torque was no longer produced by the footboard.

#### Carton box opening tool (CBOT)

Saline solution is a very commonly used consumable in a hospital. During peak seasons, more than 20 carton boxes of saline solution would be unpacked by staff daily and distributed to relevant departments. Although the carton boxes were sturdy, general unpacking tools such as cutters are prohibited as the saline solution is packed in plastic bags and could be damaged by sharp objects such as cutters. Moreover, small cutters or sharp instruments are not allowed to be used in view of the infection control concern and caution wordings 'Use no sharp instruments' are clearly marked on the box surface. Staff could only use their bare hands to pull open the boxes with considerable force which posed a risk of injury from repetitive pulling. Traumas to the hand related to these repetitive movements of opening carton boxes with the hand were reported. Before the CBOT was invented, there were two cases of injury related to carton box opening which affected 100% of the hospital assistant staff in that department.

In this connection, an opening tool for the carton box was developed. CBOT consists of two flat stainless steel plates (200 mm in length) with a handle (figure 4). It could be inserted into the gap of the carton box as a substitute for bare hands with estimated 50 mm long fingers. According to the torque equation (1), the force is inversely proportional to the distance of the effort arm. Therefore, the apply force could be reduced by 75% in theory as the distance of the effort arm was increased by 300% after applying CBOT. The risk of straining joints, muscles and tendons with use of bare hands was minimised.

#### GCTS at dangerous goods store (DG store)

Owing to the limited space of the DG store and the requirement of a medical gas supplier, medical gas cylinders were placed on different V-shaped racks of the shelves. Small and light cylinders would be placed on the upper rack while middle-sized cylinders would be placed at the bottom, according to the OSH standards. A special cylinder with size Gx (175 mm in diameter and 584 mm long and 14–16.6 kg in weight) was used to store Entonox gas, which has to be placed horizontally as required by the gas supplier Linde

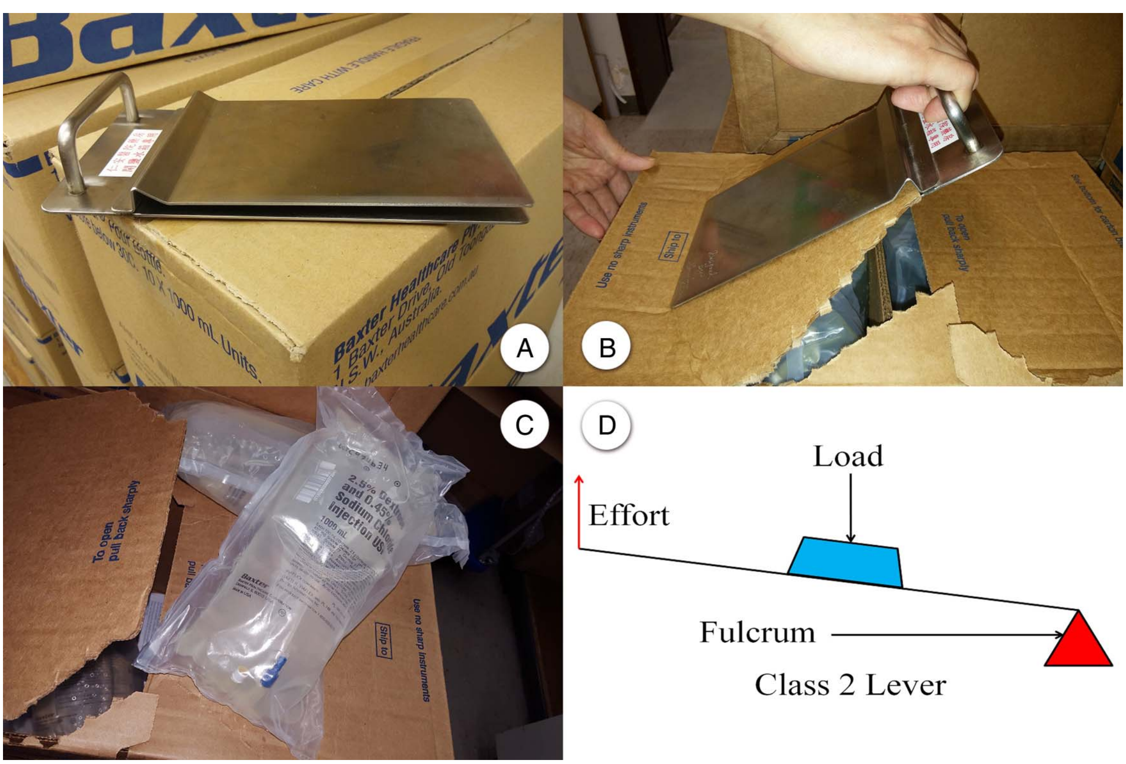


**Figure 4** The carton box opening tool and its operation with consideration of force mechanics. (A) Carton box opening tool (CBOT) consisted of two flat stainless steel plates with a handle. (B) The potential risk of causing repetitive stress injury to fingers and wrist has been minimised by using CBOT. (C) Sharp instruments are not allowed to use as they may damage the bags of saline solution inside the carton box. (D) By the application of CBOT as a 'class II lever system'. The distance between pivot and effort must be greater than the distance between weight and pivot, and this will translate into a good mechanical advantage.

HKO. The OSH committee was informed that staff need to bend down and drag out the cylinder from the bottom of the rack and may easily sustain back injury.

The GCTS, which consists of two parts, was introduced. For the storage part, nylon rollers were installed on the rack to assist the horizontal movement of cylinders. GCTS was also made according to the height of the lowest rack to assist in the transfer. The roller bearings on the trolley (figure 5) help make the sliding transfer easier. Risk of injury from lifting heavy gas cylinders was minimised even when there was only one person assigned to the task. When the cylinder is lifted to an upright position, it could be easily transferred to a hospital gas cylinder transfer cart (figure 5) safely.

In the future, GCTS would be integrated into the transfer cart as one single process. In order to reduce wastage of discarding the existing trolleys, all trolleys were to be replaced in stages and until they had reached the end of their product life cycles.

## DISCUSSION

The OSH management of healthcare workers has consistently drawn widespread attention as it is perceived as a substantial source of economic drain and manpower loss. While standards development and training reinforcement remain the core in OSH management, minimising ergonomic risk factors through design or redesign of equipment is worth further exploration,[12 14 15] although it was still uncommon in developed and developing countries. This study described how manual handling related injuries were minimised through innovation in tool modifications.

### Effectiveness of the tools

Patient-handling tasks and load lifting process are known as the major precipitating factors for musculoskeletal disorders among healthcare workers. While the process of manual handling operations is inevitable in the healthcare sector, using an ergonomic approach with consideration of human factors for work and equipment design has been found to be effective in relieving musculoskeletal stress.[16 17]

Principles of ergonomics were incorporated in the development of the tools described in this study and they were developed to address a wide range of manual handling activities, including patient handling, lifting, carrying, holding, pushing and pulling. These tools were designed to remove potential risks arising


**Figure 5** Gas cylinder transfer system. (A) Friction was reduced with the installation of nylon rollers between cylinder and the rack. A trolley was designed to hold and transfer the cylinder. Frictional force on cylinders could be reduced by similar nylon rollers on the trolley. There are 'markings' on the trolley and the rack for proper alignment. (B) A safety lock could be used to secure the cylinder when the cylinder was transferred from the rack to the trolley. (C) The trolley could be lifted up to a vertical position for safely transport. (D) A hospital gas cylinder transfer cart was used for safe transport of cylinder.

from manual handling tasks. Repetitive workflow that possibly leads to injury was streamlined and the number of staff involved in these tasks was reduced, which in turn minimised their exposure to potential risks. Since the introduction of the tools, no incidents or reports concerning the aforementioned procedures were noted.

Durability and cost-effectiveness of tools are other concerns about development of these tools. Users' feedback and comments are valuable and will be incorporated into the design. The end products are therefore highly customised according to staff's need. Working guidelines prepared by the engineering team will also be provided to ensure proper and safe use of the tools; this laid a favourable foundation for the durability of these tools.

Cost-effectiveness was crucial for the hospital to sustain its commitment on OSH issues. Costs incurred in developing these tools were low. Some of the materials used were recycled from unused equipment, such as the soft pad used in OTFT. No additional costs for manpower were required as the tools were merely designed and produced by an in-house engineering team. The estimated costs of the tools are summarized in table 1.

### Adoption of a multidisciplinary approach

Perceptions of the employer and staff on their responsibilities on occupation-related injuries might vary. Therefore, the commitment of management to promote and maintain workplace safety was an utmost prerequisite for any OSH initiatives. Chaired by senior management, the OSH Committee in Union Hospital has been in operation for 5 years to oversee hospital-wide OSH issues. Committee members of various professional disciplines fostered multidimensional analysis towards OSH issues, resulting in a more holistic approach in arriving at an optimal solution.

Union Hospital encourages two way communications. Feedback from the staffs report was carefully addressed in well-established communication channels, for example, OSH representative meetings. Staff engagement has always been considered effective in implementing change and improvement. Such a bidirectional communication and participatory approach nourishes the innovative solution to the problem, as well as builds up mutual trust to pursue further the path to staff safety in the hospital.[18]

### Promoting safety culture

Building a safety conscious culture is not easy despite its importance in reduction of injuries and incidents.[19] The successful delivery of final products in this study required an evolutionary change of attitude and effective communication between front line staff and management. Such a process was vital in building up the organisation's OSH safety culture, arousing staff's awareness on work-related risks and facilitating gradual development of the innovative design.

Although manual lifting of patients arriving in taxi or private cars is not frequent, the risk of severe injury during the transferring process should not be overlooked. RTP is therefore very important to ensure staff's occupational safety. The other three tools, OTFT, CBOT and GCTS, are being used daily to prevent repetitive strain injury. A high usage rate of these innovative tools (table 1) reflected the increased staff awareness on safety in surgical procedures, transporting procedures and lifting procedures. Working guidelines are available for the use of each tool. Staff are trained before they use the tools. The usage rate is 100% as staff are required to comply with working guidelines. Besides, the OSH team and Estate Manager would conduct regular evaluation on the usage rate of each tool by asking and interviewing individual staff.

## CONCLUSION

The majority of occupational injuries can be prevented in a cost-effective manner. In this paper, innovative solutions to OSH risks were described. Positive effects have been observed as indicated by zero incidences of related injuries at relevant worksites in the past 2 years. In addition to improvement in staff productivity and work efficiency, the implementation process has fostered a safety conscious culture and safer workplace practices, resulting in a high satisfaction and compliance rate in daily OSH practice.

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