Published in final edited form as:

J Telemed Telecare. 2009 ; 15(8): 377–382. doi:10.1258/jtt.2009.090309.

A multi-institutional mobility model for regional deployment of Telesynergy telemedicine systems

Larry L Schenken^{*}, Dwight E Heron[†], Cheng B Saw[‡], and Julian W Proctor[§]

^{*}Radiation Oncology Community Outreach Group, UPMC McKeesport Hospital, McKeesport, Pennsylvania

[†]Department of Radiation Oncology, University of Pittsburgh Cancer Institute, Pittsburgh, Pennsylvania

[‡]Division of Radiation Oncology, Penn State Milton S Hershey Cancer Institute, Hershey, Pennsylvania

[§]Department of Radiation Oncology, Jameson Health System and UPMC Cancer Center, New Castle, Pennsylvania, USA

Summary

The Telesynergy workstation is a remote medical consultation system that provides medical staff with the means to collaborate with one another on cancer research and treatment. There are about 25 systems in use around the world. In order to share the equipment with five community hospital partners in Western Pennsylvania, we designed and implemented a transport system for the workstation. Small groups can be accommodated within the trailer and larger groups can participate inside a building when the system is offloaded at a suitable site. We designed special transport cases for the main components and chose a trailer suitable to move them by road. The transport cases were secured by inexpensive, ratchet style tiedown devices made of woven nylon webbing with steel end hooks. Calculations suggest that these restraints are sufficient to protect the equipment in a 48 km/h vehicle collision. During the first 12 months, we moved the trailer more than 700 km without system damage. Mobile videoconferencing seems to be successful on both environmental and cost grounds.

Introduction

The Telesynergy workstation is a remote medical consultation system that provides medical staff with the means to collaborate with one another on cancer research and treatment, irrespective of their location. The initial version of the system included comprehensive DICOM scanning, transmission and storage software to accommodate the highest image resolution required by medicolegal guidelines. The system can be used to present a variety of electronic, micrographic or direct patient images during multi-site videoconferences. It can also be used to archive images via DVD recording and high resolution colour printing. At present, over 25 institutions worldwide use the Telesynergy system.¹⁻⁵ The system is shown in Figure 1.

In September 2003, the National Cancer Institute provided funds for two Telesynergy medical consultation workstations to promote telemedicine activities in the western Pennsylvania area surrounding Pittsburgh. One local workstation is based permanently at the McKeesport Hospital near Pittsburgh; the other is located at our program ‘mentor’, the Steitman Cancer

Center at Washington University Hospitals in St Louis, Missouri. However, we wished to share the latter equipment among our five community hospital partners in Western Pennsylvania. We therefore designed and implemented a transport system for the workstation, as briefly described in 2006.⁶ Our first year's experience is summarized below.

Equipment

In order to move the workstation we designed special transport cases for the main components and chose a trailer suitable to move them by road.

Trailer

The criteria for selecting the trailer were: (1) a total cost of not more than \$16,000 (\$1 = 0.74 Euro); (2) sufficiently large for small group conferences within the trailer (when larger group conferences were required, the equipment could be unloaded at a suitable venue); (3) adequate lighting and air conditioning for weather extremes; (4) equipment security from vandalism and theft; (5) equipment protection from road vibrations or minor collisions; and (6) ease of loading and unloading equipment.

Based on these criteria, we selected a trailer with a rear door that dropped down to form a loading ramp (only one person required) to allow large objects to be loaded into the trailer, as shown in Figure 2. This type of trailer is designed to move heavy objects such as motorcycles, snowmobiles or 4-wheel all terrain vehicles. The chosen trailer (Desert Fox VS, Northwood Manufacturing, Winchester VA) could accommodate wheeled vehicles weighing up to 1436 kg. The trailer was modified by removing non-essential components and adding a front cabinet/workbench, windows and exterior floodlights. When delivered, the trailer had a gross weight rating (GVWR) of 3572 kg, including a cargo load capacity of 1436 kg. (The GVWR is the maximum allowable total weight of the trailer when loaded, i.e. including the weight of the vehicle itself plus fuel, passengers, cargo and the trailer tongue weight). The usable floor measurements were 2.44 m × 5.03 m. The trailer temperature was maintained by a 9 kW propane furnace, or a back-up 220 V electric heating system, and a 4 kW air conditioning system.

The total trailer cost including front workbench, windows and exterior floodlights for night-time ramp illumination was \$11,000. The tiedowns and the 220 V heating system cost \$450. Comprehensive insurance (replacement value for theft, damage, collisions, fire) cost about \$2000 per year. Over a five-year period this represents \$858 per year for each of the five participating institutions.

Equipment cases

The Telesynergy equipment is normally mounted on carts to facilitate moving it inside a hospital. However, these carts are not suitable for road transit. For transport, the large components were removed from the carts and stored in specially-designed plywood packing cases with hinged locking lids as shown in Figure 3. The equipment cases were lined with low-density foam, with high density foam for all surfaces touching equipment. The cases were made in house.

1. Large plasma screen. The large 1.22 m plasma screen was protected by a special heavy duty case constructed with 10 cm rollers and a tow rope;
2. Small LCD monitor screens. Similar smaller padded transport cases were made for the three system monitors. These cases were placed on the wheeled large case shown in Figure 3C to transport the equipment to and from the trailer;

3. Microscope. The microscope base had a wooden frame and internal tie-down straps that crossed over the microscope base and arm in an 'X' pattern to minimize the risk of damage. The foam-lined case top was then locked to the base with six hasps. The closed microscope case was then placed on a cart to move it into the trailer.

Equipment restraint

The minimum performance criteria for securing cargo in the USA are defined by the general regulations which specify the working load limit for tiedown assemblies.⁷ (Note that the working load is defined as one-third of the rated capacity, or tensile strength). The most straightforward general tiedown regulations state that total tiedown capacity on an object shall accommodate at least half of the object's weight. More detailed regulations require a tiedown that will resist:

- 0.435 g deceleration in the forward direction;
- 0.5 g acceleration in the rearward direction;
- 0.25 g acceleration in a lateral direction.

The weights of the main Telesynergy components, including their packing cases, were:

- Large plasma screen, 113 kg;
- Three small display screens (monitors), 18 kg each;
- Microscope, 25 kg;
- Main cart, 136 kg;
- Two secondary carts, 45 kg.

Thus for the heaviest object, the main cart, a tiedown strap with a working load limit of at least 68 kg was the required minimum. Ratchet style tiedown devices made of woven nylon webbing with steel end hooks are readily available from hardware stores or from Internet-based vendors. We identified two standard types suitable for our purposes: one with 2.5 cm wide straps providing a rated working load capacity of 136 kg, and a second heavy-duty type with 7.5 cm wide webbing providing a 500 kg rated working load capacity. Both types of belt are commonly used for cargo, and are inexpensive.

To provide an additional safety factor, we used a total of five of the 136 kg straps for each of the instrument carts. Because of abrasion potential at the corners of the plasma screen case and the case position at the rear wall of the trailer, we also used four of the 500 kg straps with wide webbing. These extra belts provided inexpensive assurance. Other safeguards were added to the restraints for the plasma screen case:

1. Additional washers were added to the eyebolts in the rear wall (ramp) to reduce the possibility of 'pull-through';
2. Blocks with holes drilled in them were used to receive the wheels of the plasma screen cart. The blocks had a rubber coating to enhance their coefficient of friction.

Finally, the instrument carts were placed on the trailer floor between detention plates (required by the regulations for wheeled equipment), the wheels were locked, and the carts were then strapped down with ratchet tiedowns. The carts were clamped to floor plates bolted to the sub-floor trailer joists using two straps in parallel fashion and two straps in a cross-over pattern. A fifth belt was added over the work surfaces (counter tops) of each cart to minimize vibration.

First year's experience

During the first year of operation we moved the system four times. There were no cases of damage to the vehicle or the equipment, and no injuries to personnel.

The videoconferencing CODECs, which were originally designed for ISDN use, were converted to Internet Protocol, so that ISDN charges were eliminated. Most medical institutions now have sufficient Internet bandwidth to provide satisfactory videoconferencing.

The trailer and equipment proved easy to move, provided the trip was planned carefully and suitable loading/ unloading areas were identified in advance. Packing and loading the equipment into the trailer took two people about 60 min. With experience, setting up the system in a new location required about 90 min.

A full plan involves: (1) advanced planning for videoconferencing usage at the relocation site; (2) activation of any required Internet access and electrical power at the relocation site; (3) pre-travel surveillance of the transit route when necessary; (4) scheduling of assistants and parking at both sites to set up or remove equipment; (5) scheduling of the anticipated educational or consultation events at the relocation site; and (6) coordinating with medical and support staff at the relocation site.

Except for events such as a highway crash in excess of our maximum calculated 48 km/hr (30 mph) impact speed, we consider that the equipment is well protected during highway transit. In the first year of use, the only event of note was a very slight cosmetic scratch on a computer CPU case that occurred during initial loading into the trailer. This problem was solved by adding an extra ratchet tiedown to the case and cart frame to prevent further movement. We have moved the trailer more than 700 km without system damage.

The environmental controls worked well and the heating system (either propane during transit or 220 V electricity when parked) was able to maintain temperatures of 21–24°C in winter. We prefer to schedule summer relocations for the early morning or late evening because of the lack of air conditioning during the transit. When the trailer is stationary, with the air conditioning turned on, a temperature excess of 10°C can be recovered in 12–15 min. The trailer is well insulated, rides smoothly on torsion suspension, has adequate 23 cm ground clearance, and is relatively easy to move about in tight areas. However, it requires a minimum overhead clearance of 3 m because of the rooftop air conditioner, so care must be taken to avoid canopies and low overhangs at hospital locations.

Discussion

In an initial review of the highway safety literature, we found two useful websites. The first deals with braking distances, reaction times and other stopping issues⁸ and the second with estimating the forces associated with crashes at different speeds.⁹ The general literature about cargo securement contains a number of similar standards concerning cargo restraint during road transport. Most regulations specify the position, installation and strength requirements for lock down points and the hardware to be used. Clear and helpful guidance is provided in the US transport regulations⁷ and similar Australian regulations.¹⁰ Readers should consult the appropriate local government regulations for their own region or country.

There are no general specifications for the strapping or tiedown capacities necessary to secure a load during a vehicle crash. This is probably because of the unpredictable factors associated with impact speed, type of impact (e.g. side, rear, front) and the variety of vehicles that could be involved. For any collision, the key factors for restraining equipment are the mass (weight)

of each component, the velocity of the vehicle (and its contents) at the moment of impact, and the deceleration forces during the collision.

We calculated⁹ the average forces experienced in a collision based on an impact between the front of our trailer-towing vehicle and the rear of a stationary vehicle ahead on the roadway. In such a crash, the kinetic energy of the moving vehicle is dissipated by crushing the two ends of the vehicles involved. A vehicle's 'crush zone' is designed to absorb energy by deformation of the metal components. The crush zones for most pickup truck front ends are 91 cm, and the crush zones for most automobile rear ends are 61 cm. This gives a total crush zone distance of 152 cm. The average calculated forces are shown in Table 1.

The number of straps we employed was sufficient to restrain the equipment in a 48 km/hr crash. For additional assurance, extra straps were used as described above. We closely reviewed all of the regulatory sub-sections related to US cargo securement requirements, and verified that the relevant subsections on hardware strength, belt placement, and tightening issues as well as wheeled cargo issues were accommodated. For the sake of simplicity, the Table 1 estimates represent a reasonable approximation of higher estimated 6.0 g crash force risks not identified by regulatory requirements, yet exceeding established standards for cargo tiedowns.

Environmental and other considerations

It is clear from our experience that there is considerable potential for reducing costs and increasing efficiency by sharing medical equipment between institutions. There are also associated environmental benefits.

1. Carbon footprint reduction. We used three carbon footprint calculators to calculate the environmental impact of a mobile videoconferencing facility.¹¹⁻¹³ The results were similar for the following example: assuming a round trip distance for a conference of 160 km, relocating the equipment using a conventional pickup truck with an average fuel consumption would result in the emission of 74 kg of CO₂. In contrast, for 25 cars to move to the host site for the conference, the total emissions would amount to 1060 kg of CO₂, a 14-fold increase in CO₂ production.
2. Cost savings. With the same round trip, driving times of 2.5 hours and 25 cars (two people each), there is a total of 125 hours of non-productive driving time. At an average \$60 per hour pay, the labour cost for staff driving to a meeting is \$7500. Thus in this example, \$1462 of fuel and \$7500 of staff driving time could be saved by moving a videoconferencing system to a remote site rather than requiring attendees to travel to the central site. Note that the labour charges for packing, loading, unloading and re-set up for moving a Telesynergy system and returning it to its original location are based on a pay rate of only \$20 per hour per person. The total time for loading and set-up are 90 minutes for each of two persons, plus driving time of 2.5 hours for one person for each direction of the relocation. The total labour requirements to move the equipment during the trip would be about 11 hours, or \$220.

Thus there are good reasons to consider mobile videoconferencing on both environmental and cost grounds.

Conclusions

The literature contains many articles about the use of videoconferencing in health care, almost all of which concern fixed locations. There are relatively few reports of mobile videoconferencing or remote medical consultation systems, most of which concern relatively expensive, self-powered large vehicles equipped with satellite links for transmission of medical images.¹⁴⁻¹⁶ The present report appears to be the first which documents the use of a low-cost

trailer. Our experience shows that mobile videoconferencing may be suitable for smaller community-based hospitals and clinics. If appropriately designed, a mobile system can be effective and efficient, easily facilitated, and convenient for video consultations or other medical education applications.

Acknowledgments

We thank Professor John Wiss (Department of Mechanical Engineering, Carnegie Mellon University, Pittsburgh, USA) for reviewing the paper and for suggestions about cargo securement and tiedown. This work was supported by NIH grant 5U56-CA105486. We are also grateful for the assistance of Dave Partlow (Northwood Manufacturing, Winchester, VA). Telesynergy is a registered trademark.

References

1. National Cancer Institute. Cancer Disparities Research Partnership Program. See <http://www3.cancer.gov/rrp/CDRP/index.html> (last checked 27 June 2009)
2. National Institutes of Health. Overview of Telesynergy. See <http://telesynergy.nih.gov/overview.html> (last checked 27 June 2009)
3. National Cancer Institute. Telesynergy v3 Current Component List. See http://www3.cancer.gov/rrp/CDRP/telesynergy_components.html (last checked 27 June 2009)
4. Murdock J, Jaffe ES, Wilson WH, McManus DT, Alexander HD, Morris TC. Aggressive natural killer cell leukemia/lymphoma: case report, use of telesynergy and review of the literature. *Leuk Lymphoma* 2004;45:1269–73. [PubMed: 15360011]
5. McAleer JJ, O'Loan D, Hollywood DP. Broadcast quality teleconferencing for oncology. *Oncologist* 2001;6:459–62. [PubMed: 11675525]
6. Schenken LL, Saw CB, Heron DE, Proctor JW, Miller D. P69. A multi-institutional regional/mobility model: deployment for Telesynergy telemedicine systems. *Telemed J E Health* 2006;12:264–265.
7. US Department of Transportation. Federal Motor Carrier Safety Administration (see section 393.102 and 393.104). See <http://www.fmcsa.dot.gov/> (last checked 27 June 2009)
8. CSG Network. Vehicle Stopping Distance and Time. See <http://www.csghnetwork.com/stopdistinfo.html> (last checked 27 June 2009)
9. Georgia State University Hyperphysics. Forces in Car Crashes. See <http://hyperphysics.phy-astr.gsu.edu/hbase/carc.html> (last checked 27 June 2009)
10. National Transport Commission Australia. Load Restraint Guide. See <http://www.ntc.gov.au/viewpage.aspx?documentid=00862> (last checked 27 June 2009)
11. Sustainable Travel International. Calculate your personal carbon footprint. See http://www.sustainabletravelinternational.org/offset_customers/op_carboncalcs_4.html (last checked 27 June 2009)
12. Carbon Footprint Ltd. Carbon Footprint Calculator. See <http://www.carbonfootprint.com/calculator.aspx> (last checked 27 June 2009)
13. Take Part. Calculate Your Impact. See <http://www.climatecrisis.net/takeaction/carboncalculator/> (last checked 27 June 2009)
14. Takizawa M, Miyashita T, Murase S, et al. Mobile hospital – real time mobile telehealthcare system with ultrasound and CT van using high-speed satellite communication. *Igaku Butsuri* 2003;23:51–8. Japanese. [PubMed: 12832865]
15. Arbeille P, Ruiz J, Ayoub J, et al. The robot and the satellite for tele-operating echographic examination in Earthisolated sites, or onboard ISS. *J Gravit Physiol* 2005;11:P233–4. [PubMed: 16240525]
16. Miyashita T, Takizawa M, Nakai K, et al. Realtime ultrasound screening by satellite telecommunication. *J Telemed Telecare* 2003;9(Suppl 1):60–1.

Figure 1.

(A) A general view of the Telesynergy remote consultation system. Note the three basic workstations: the first is on the left, the second is in the centre under the plasma screen and the third is on the right. (B) an accessory computer for videostreaming conferences to websites, a document camera for viewing films and other images, a laptop computer to access remote desktops or medical imaging websites on intranets, a DICOM monitor and a digital printer. (C) the central communications workstation for managing videoconferences and switching between image sources (the right hand monitor shows self-view while conferencing). (D) the workstation for photomicroscopy and an X-ray film image scanner

Figure 2.

Rear view of the trailer after loading at UPMC McKeesport Hospital. The rear door of the trailer (within the black edges) folds down to form a loading ramp. In the ramp position, equipment can be loaded or unloaded easily. Opening and closing the door requires only one person because the weight is counterbalanced by heavy springs at the side. Note the vehicle's high ground clearance

Figure 3.

(A) View towards the rear of the trailer showing auxiliary lighting. (B) interior view of the trailer, looking towards the front. The small screen monitors are strapped to the workbench. The microscope case is strapped to the floor. (C) interior view, looking towards the rear. The plasma screen case has been strapped into place prior to blocking. (D) the microscope case tiedown system

Table 1

Average force on an object in a 48 km/hr (30 mph) crash between a tow truck/trailer front end and a car rear end (152 cm combined crush zone)

Object	Weight (kg)	Average crash force (kg)	Tiedown requirement (kg)*	Minimum number of retaining straps†
Main cart	136	819	410	4
Plasma screen and case	113	683	377	3
Second carts	45	273	136	2

* The (rearwards) tiedown requirement was 0.5 g ⁷

† The straps were assumed to have a working load of 136 kg each