Canadian Coordinating Office for Health Technology Assessment
Office Canadien de Coordination de l'Évaluation des Technologies de la Santé

A COMPARISON OF FIXED AND MOBILE CT AND MRI SCANNERS

NOVEMBER 1995

PROJECT DIRECTORS
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EXECUTIVE SUMMARY

The Canadian Coordinating Office for Health Technology Assessment (CCOHTA) was requested to conduct a comparison of fixed versus mobile computed tomography (CT) and magnetic resonance imaging (MRI) scanners. This comparison includes a determination of the ability of mobile units to function in harsh climates and considers other implications such as cost and safety.

CT and MRI are both diagnostic imaging modalities which produce slice images of various anatomical structures. The theory behind each is very different. CT uses x-rays while MRI takes advantage of the magnetic properties of ions in the human body, particularly hydrogen ions. Mobile technology has been in use in the United States for several years, with its emergence being driven by social, economical, and technological factors. CT was one of the first technologies to be available in a mobile form and the introduction of mobile MRI units is largely due to the success experienced by the mobile CT. Although there are several mobile CT and MRI scanners available in the United States, the interest in and the use of mobile scanners is decreasing, possibly due to changes in the economy, technology or a surplus of scanners. To date there are no mobile CT scanners and two mobile MRI units available in Canada.

The CT and MRI scanners placed in mobile trailers are technologically identical to the respective scanners used at fixed sites. The scanning rooms in mobile trailers may be smaller than the scanning rooms at fixed sites so more patients may experience claustrophobia. With strict quality control measures in place and an experienced crew, the image quality of scans taken in mobile units appears to be no different than that of the scans taken at a fixed site. The siting requirements of fixed sites are more extensive than what is required of a mobile unit. Historically, with mobile MRI specifically, care had to be taken in the placement of the scanner but several technological advancements now allow the trailer to be placed closer to parking lots and patient areas.

In order to ensure the optimal performance of scanners, the internal temperature and humidity of mobile units must be maintained at certain levels, regardless of the weather outside. Mobile units are designed to withstand temperatures of -20°F to 110°F and optional heaters are available for colder temperatures. In the United States, there have been scanners operating for years in states such as Alaska, Minnesota, California, and Rhode Island which have climates similar to those found in various parts of Canada.

The cost of fixed and mobile CT and MRI scanners include both fixed and operating costs. The fixed costs vary according to the type of scanner (CT or MRI) and siting requirements (renovations, trailer, etc.). Operating costs (staff, supplies, upgrades, etc.) for mobile units tend to be higher than for fixed sites, however, this should be weighed against the responsiveness of mobile technology to volumes and other costs such as those direct and indirect costs experienced by the patient. Mobile technology also provides a means with which to provide CT and MR diagnostic services to multiple facilities within a given geographic area that individually would not have the volumes to justify the purchase of a fixed scanner.

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INTRODUCTION TO CT AND MRI TECHNOLOGY

Computed tomography scanners first appeared in hospitals in England and the United States in 1973. The first commercial scanners were designed for brain scanning, however, CT technology is now being used to image many anatomical structures (O'Donovan, 1992). Put simply, CT can be described as a three-dimensional x-ray technique. To generate each image, an x-ray beam is aimed through the patient at many different angles. Rather than striking film as in standard radiography, the x-rays are detected by radiation detectors that stimulate an electrical impulse that is then quantified and stored in a computer. Through the computer, CT images can be manipulated and analyzed. The advantages of CT over standard x-ray images is that CT has a greater sensitivity to small changes in tissue density and its images are "slices" of anatomical structures that are not superimposed (Grossman, Katz, Santelli, Math & Wasenko, 1994).

Although magnetic resonance imaging (MRI) was first described in the 1940s, it was not until 1977 that the first human whole-body scan was performed. Since then there has been and continue to be many improvements in image quality and the scanning process (Iezzoni, Grad & Moskowitz, 1985). MRI has been found particularly useful in imaging the brain, spine, and musculoskeletal system. MRI scanners are similar in appearance to CT scanners and also produce computer-generated images that are slices of anatomy (Grossman, Katz, Santelli, Math & Wasenko, 1994). The process, however, behind obtaining the images is very much different. For most clinical applications, MRI takes advantage of the magnetic properties of hydrogen which is in abundance in the human body. A patient is placed into a powerful magnetic field with controlled radiofrequency impulses being transmitted. The hydrogen protons within the patient will then emit a radiofrequency signal that will be processed by the computer to produce the image (Ross, 1992).

MOBILE TECHNOLOGY

The emergence of mobile technology has been driven by social, economical and technological factors. It consists of a van or tractor and trailer which is custom-designed to accommodate a particular technology such as CT and MRI scanners, extracorporeal shock wave lithotripsy units (ESWL), gamma cameras, etc. CT was one of the first technologies to "go mobile" due to the initial high cost of the technology and the large outpatient population which it served ("Technology on Wheels", 1987). The reasons for the introduction of mobile MRI units are largely similar to those associated with CT scanners and further encouraged by the success experienced by that technology.

The United States has been using mobile technology for years. It is estimated that there are approximately 6,000 CT scanners in the U.S. and in 1987 it was estimated that there were 300 to 400 mobile units. At that time the number of mobile units was beginning to decrease ("Technology on Wheels", 1987). Appleby (1995) estimates that there are approximately 4,000 MRI units in operation. Of those, close to 700 are mobile in nature. In Canada, there are 223 CT scanners (Canadian Coordinating Office for Health Technology Assessment, 1995) and apparently no mobile CT units (J. Forbes, A. Ford, H. Gillis, personal communication). There are 36 installed MRI units in Canada being used primarily for clinical applications (Canadian Coordinating Office for Health Technology Assessment, 1995). In addition to these units, British Columbia introduced a mobile MRI unit in March 1995 (P. Chapin, personal communication) and in July 1995, a mobile MRI unit began operation in New Brunswick (M. Barry, personal communication). Both are 1.0T units.

The literature which discusses and identifies issues surrounding mobile technology was published predominately in the 1980s, and in fact, there are several common issues that are shared between mobile CT and MRI technology. There tends to be little information available in the literature today on this topic and according to various sources, the problems identified in the past have largely been resolved. The market for mobile technology is driven by price, and the higher the price of the [permanent] unit, the more demand there is for mobile units ("Technology on Wheels", 1987). In fact, it appears that the demand for both mobile CT and MRI scanners is declining in the United States perhaps due to both economic factors and an apparent surplus of scanners.

The Canadian Coordinating Office for Health Technology Assessment (CCOHTA) was requested by a provincial government to complete a comparison of fixed versus mobile MRI scanners in Canadian climates. More specifically, CCOHTA was asked to determine the effectiveness of mobile scanners in winter climates such as in the northern regions of Canada and consider other implications such as cost and safety. Further to this request, CCOHTA was asked to broaden the scope of the project to include a similar comparison of fixed versus mobile CT scanners as well.

METHODOLOGY

For literature relating to CT scanners, Table 1 describes the databases that were searched and the keywords utilized.

TABLE 1 - Literature Search on CT Scanners

Database	Keywords
Nursing & Allied Health (CINAHL) • from 1983 to 1995	"tomography" and ("mobile" or "shared")
Health Planning & Administration (HEALTH) • from 1975 to 1995	"tomography" and ("mobile" or "portable")
MEDLINE • from 1966 to 1995	same as above
Health Periodicals • from 1976 to 1995	same as above
Health Services/Technology Assessment Research (HSTAR) • from 1985 to 1995	"tomography" and ("mobile health units" or "hospital shared services")

For literature on MRI scanners, Table 2 describes the databases and keywords used in that search.

TABLE 2 - Literature Search on MRI Scanners

Database	Keywords
International Health Technology Assessment	"magnetic resonance imaging" and "mobile"
MEDLINE • from 1966 to 1995	"magnetic resonance imaging" or "MRI" or "magnetic resonance" combined with "mobile" or "portable" or "shared"
Health Planning & Administration (HEALTH) • from 1975 to 1995	same as above
Health Periodicals • from 1976 to 1995	same as above
Nursing & Allied Health (CINAHL) • from 1983 to 1995	"magnetic resonance imaging" and ("mobile" or "portable")
ECRI Health Technology Assessment Information System database	"magnetic resonance imaging" and "mobile"
Health Services/Technology Assessment Research (HSTAR) • from 1985 to 1995	"magnetic resonance imaging" and ("mobile health units" or "hospital shared services")

All references found through the searches in Tables 1 and 2 were limited to those of the English language.

Using the ECRI "1994 Health Devices Sourcebook" manufacturers of CT and MRI scanners were identified and several were contacted for information on technical specifications and costs. To determine the status of mobile MRI technology in Canada, various representatives of the New Brunswick and British Columbia Ministries of Health were contacted. Other sources of information such as associations, hospitals, and consultants were also contacted.

TECHNICAL ISSUES

Common Issues to Both CT and MRI

Many of the advancements achieved in the system and trailer design of both mobile CT and MRI scanners may be attributed to the growth and development of the mobile CT scanner (Herman, 1986). From a technical point of view, the scanners placed in trailers are identical to the scanners available at fixed sites (A. Ford, personal communication). Although the scanners are not different, there is usually more servicing required for the mobile unit. The actual number of times the mobile scanner needs to be serviced is dependent upon how often the mobile unit is moved and throughput (J. Forbes, personal communication). The tractor and trailer which are used to transport mobile scanners also require servicing and how often this is required is dependent on how often and how far the unit is travelling on the road (P. Chan, personal communication).

Although a fixed site may have some limitations in how large the scanning room is, they are not quite so severe as that of a mobile unit. The interior of the mobile trailer has space limitations, and as with a fixed unit there has to be a scanner, operator consoles, computers, air-conditioning, humidification units, and possibly film processors and viewing screens, etc. to be installed. Up to 10% of patients have experienced claustrophobia in mobile units as compared to 1-4% in fixed MRI units for example, and unfortunately it is not possible to enlarge the scanning room in mobile units (Herman, 1986; Rinck, 1991).

There is a perception that when CT or MRI technology is mobile, image quality is impaired. Herman (1986) states that "images from mobile CT and MRI scanners are reported to be as good as or better than images obtained at fixed sites" (p. 93). Manufacturers concur while stressing that the mobile unit must be well-maintained and subject to at least the same number of quality control checks as a fixed unit (D. Ragan, personal communication). Anecdotally, radiologists from both British Columbia and New Brunswick report that the image quality produced by the respective mobile MRI units may actually surpass that of MRI units at fixed sites (R. Walter, M. Barry, personal communications).

Image quality is not only influenced by hardware and software components but by "human" factors as well (Padikal, 1987). Trailer design, which was discussed briefly above is tied to operator comfort and morale which impacts on image quality (Herman, 1986). One potential problem with mobile scanners that may impact on image quality is that of having a dedicated crew. At a fixed site, staff such as technologists and physicians are in contact with the scanner almost daily enabling them to obtain and retain a certain level of proficiency in operating the scanner and interpreting results.

For that reason, it is preferable for a mobile unit to have a dedicated crew, however, that may not be possible depending on how far and how often the unit has to travel (A. Ford, personal communication). This could perhaps be rectified by access to a tertiary care centre where experienced radiologists would provide assistance in interpreting images obtained at a mobile site.

CT Scanner Issues

The CT scanner easily lends itself to being placed into a trailer and this enabled it to become the most common type of mobile imaging in the United States (ECRI, 1987). Servicing both fixed and mobile CT scanners takes approximately half a day and in either case will be required as often as once a month or up to once every six months. This is dependent on throughput and in the case of a mobile CT scanner, how often it is moved (J. Forbes, personal communication). The warm-up time required for fixed and mobile units is about the same and varies from manufacturer to manufacturer, however, it is typically five to eight minutes (A. Ford, personal communication). Mobile CT scanners may also be upgraded in the same manner as fixed units (D. Ragan, personal communication).

The siting requirements of fixed and mobile CT scanners are different. To set up a room to hold a CT scanner, renovations are necessary including lead shielding similar to that found in a standard X-ray room. The trailers required to house mobile units are manufactured in the United States only and will also require lead shielding (J. Forbes, personal communication). Unlike older mobile MRI units, mobile CT scanners may be placed right beside the facility and near areas of high traffic (Herman, 1986).

MRI Scanner Issues

There have been several modifications made to the MRI that have made it more conducive to mobile technology. Over the past several years, the units have become lighter, smaller, and self-shielding and it is now possible to get superconductive 0.5T or 1.0T MRI units on the road (M. Janu, personal communication). Originally, the preparation time necessary to set up mobile MRI units was great and that impacted on scheduling. Newer MRI units require minimal set-up and the magnet which often needed to be ramped after each move, is now ramped during the initial calibration and remains ramped throughout each move (Siemens, 1994).

The siting of the mobile MRI scanner was typically a problem. Because of the magnetic field caused by older magnets, it was necessary to place the mobile unit away from large metal objects such as cars and care was taken to protect patients with pacemakers, aneurysm clips, etc. (Herman, 1986). Now, magnets are highly shielded and self-contained and although patients with pacemakers and aneurysm clips still require protection, the trailer may be placed closer to areas such as external walls and parking areas which were once considered too sensitive (Siemens, 1994).

An often cited advantage of mobile MRI units is the decreased cost of site preparation. A typical mobile trailer is 8 feet wide, 48 feet long, and 13.5 feet high. The actual siting consists of a flat, levelled concrete pad, an outlet, and a phone line (M. Janu, personal communication). In regions where the climate is of concern, a jetway similar to those found in airports may also be purchased. For a fixed site, the building specifications are more extensive. Some of the preinstallation work includes installation of electrical and other lines or outlets, installation of shielding in the magnet room, installation of structural reinforcements, actual renovations and so on (GE Medical Systems, 1993). It is possible for mobile MRI units to be converted to a fixed site by either positioning the trailer at one site or removing the system and constructing a fixed site (M. Janu, personal communication). Difficulties may be encountered in upgrading mobile MRI scanners due to space limitations imposed by the size of the trailer. For example, if upgrading meant increasing the number of computer cabinets, it may be difficult in a mobile unit where space is already limited (D. Ragan, personal communication).

LOCATION ISSUES

When considering mobile technology, it is important to determine the environmental conditions the unit is expected to withstand. For optimal performance of scanners, the internal temperature and humidity must be maintained at certain levels (J. Forbes, personal communication). Mobile vans are designed to meet and maintain the required internal environment for external temperatures ranging from -20°F to 110°F, and for outside temperatures below -20°F, optional heaters are available (M. Janu, personal communication). Mobile imaging units, once configured, undergo testing at U.S. environmental facilities at White Sands Laboratories in New Mexico. Inside a chamber, the mobile unit is subjected to simulated extremes in temperature and humidity to ensure that the internal environment recovers quickly each time the door is opened. As well, to ensure patient comfort, jetways and canopies may be used to protect the patient from the outside while moving from the hospital to the mobile van (Herman, 1986).

It is possible to learn from the experiences of the United States with mobile technology. According to Silver (personal communication), there are mobile scanners operating in states which have climates similar to the range of climates found in Canada. For example, there have been mobile scanners operating for years in states such as Minnesota, Alaska, Rhode Island, Arizona, and California, to name just a few. On the other hand, Gillis (personal communication) notes that a mobile mammography unit in Northern Ontario is "taken off" the road in the winter because of poor road conditions. Although the unit is still in use during that time, it is stationary and remains at only one site.

On the road, mobile scanners are subject to vibration, shock and torque as well as other forces. It is critical to know how mobile units will perform after moving from one site to another, often several times each month. Once again, extensive testing is performed on prototypical trailers at the Transportation Research Track in Ohio (Herman, 1986). For a smooth ride, particular emphasis is placed on shock absorption and special bracketry to secure the equipment (J. Forbes, personal communication). Despite all those precautions, some vibration will be experienced and require that the mobile unit be serviced more frequently than a comparable fixed unit. Quality assurance checks should also be performed more frequently on mobile scanners (D. Ragan, personal communication).

COST ANALYSIS

Monetary costs of fixed and mobile CT scanners and MRI units include both fixed and operating costs. Tables 3 and 4 below give the range of costs associated with CT scanners and MRI units respectively. However, additional costs need to be considered (for a complete picture) such as travel costs for those who have to travel for diagnostic imaging. These costs can be substantial and include disruptions in work and family life, travel costs (eg. car, plane, ambulance), accommodation, and meals (Erickson, Mackenzie, Marshall, 1993)

Fixed v/s Mobile CT Scanners

The fixed costs associated with the purchase and installation of a fixed CT scanner total approximately $700,000 for a mid-range scanner and $1,100,000 for a high-range scanner. The respective annual operating costs (supplies, maintenance, staff, etc.) may range from $180,000 to $300,000 (assuming a throughput of 20 patients/day) or from $460,000 to $760,000 (assuming a throughput of 50 patients/day). The fixed costs associated with the purchase and installation of one mobile CT scanner range from $825,000 to $1,000,000 for a mid-range scanner and from $1,225,000 to $1,400,000 for a high-range scanner. In this case, the respective annual operating costs may range from $205,000 to $340,000 (assuming a throughput of 20 patients/day) or from $485,000 to $800,000 (assuming a throughput of 50 patients/day). These costs are provided in Table 3.

Table 3 - Fixed and Mobile CT Scanner Costs ($000)

	Mid-Range CT Scanner		High-Range CT Scanner	
	FIXED	**MOBILE**	**FIXED**	**MOBILE**
Equipment Costs[1]				
CT Scanner	400	400	800	800
Mobile Trailer and Tractor	N.A.	400	N.A.	400
Building Costs[1]				
New	250	N.A.	250	N.A.
Renovative	50		50	
Siting Costs[1]				
Concrete Pad, Services, Connecting Dock	N.A.	25 - 200	N.A.	25 - 200
Total Fixed Costs	**700**	**825 - 1,000**	**1,100**	**1,225 - 1,400**
Operating Costs (yearly)				
Staff				
Service Contract[1]	60-120[2]	60-120[2]	240-480[3]	240-480[3]
Van Driver & Gasoline[4]	50	50	100	100
Equipment Upgrades[1]	0	40-60	0	40-60
Operating Supplies[1]	0-50	0-50	0-50	0-50
Facilities Maintenance[5]	50	50	100	100
	20-30	5-10	20-30	5-10
Total Operating Costs	**180-300**	**205-340**	**460-760**	**485-800**

[1] Estimates provided by J. Forbes, Picker International Canada Inc.
[2] Staff costs based on 1-2 technologists (dependent on throughput).
[3] Staff costs based on 2-4 technologists (dependent on throughput).
[4] Estimates based on average driver salary and gas consumption.
[5] Estimates extrapolated from data in Table 4.

Fixed v/s Mobile MRI Scanners

As can be seen in Table 4, the fixed costs associated with the purchase and installation of a fixed MRI can range between $2,085,000 and $4,130,00 and its annual operating costs (maintenance, staff, supplies) range between $705,000 and $810,000 (assuming a single shift).

On the other hand, the fixed costs associated with the purchase and installation of one mobile MRI (three sites) range between $2,210,00 and $3,215,000 and the annual operating costs of this mobile unit range between $725,000 and $828,000.

Table 4- Fixed and Mobile MRI Costs (in $000)

	1.0T Fixed MRI	1.0T Mobile MRI
Equipment Costs		
1.0T MR System (Configuration Dependent)	1,650 - 2,150	1,650 - 2,150
Mobile Trailer	N/A	350 - 500
Tractor	N/A	105 - 115
BUILDING COSTS		
New	900 - 1,800	N/A
Renovative	350 - 650	
Radio Frequency (RF) Shield (Site Dependent)	85 - 110	
Magnetic Shield (Shielded Magnet, Site Dependent)	0-70	
SITING COSTS		
Concrete Pad & Services **OR**	N/A	35 - 50
Concrete Pad, Services & Connecting Dock to Hospital		100 - 150
Total Fixed Costs	**2,085 - 4,130**	**2,210 - 3,215**
OPERATING COSTS (yearly)		
Staff*	150 - 180	150 - 180
Service Contract	120 - 140	155 - 180
Van Driver & Gasoline	N/A	Variable (40 - 60)
Cryogens & Magnet Maintenance	35 - 40	35 - 40
Equipment Upgrades	150	150
Operating Supplies	230 - 270	230 - 270
Facilities Maintenance	20 - 30	5 - 8
Total Operating Costs	**705 - 810**	**725 - 828**

Estimates provided by P. Chan, GE Canada.
* Staff costs are based on two technologists and one nurse.

Example

Table 5 below compares the costs associated with installing a fixed MRI in a 400 bed hospital with the costs associated with having a mobile unit serve three sites, both cases generating equal throughputs of 2,080 scans.

Table 5 - Cost Comparison Between a Fixed and a Mobile MRI ($000)

	Fixed	Mobile
Equipment Costs		
1.0T MR System	1,800	1,800
Tractor and trailer	N.A.	535
Building Costs		
Renovative	500	N.A.
RF Shield	100	N.A.
Magnetic Shield	20	N.A.
Siting Costs		
Concrete pads (3 sites @ $40 ea.)	N.A.	120
Connecting Docks (3 sites @ $80 ea.)	N.A.	240
Total fixed costs	**2,420**	**2,700**
Operating Costs		
Staff (1 shift)	180	180
Service contract	125	160
Van driver + gasoline	N.A.	66
Cryogens & magnets	40	40
Equipment upgrades	150	150
Operating Supplies	270	270
Facilities maintenance	25	24
Total operating costs	**790**	**890**
Patients' Direct Costs [1]		
Travel cost (240 km @ 33¢/km x 2 ways)	329	
Travel cost (60 km @ 33¢/km x 2 ways)		83
Total patients' direct costs	**329**	**83**
Patients' Indirect Costs [1]		
Patients' time (10h @ $50/hr)	1,040	
Caregivers' time (10h @ $50/hr x 0.5)[2]	520	
Patients' time (4h @ $50/hr)		416
Caregivers' time (4h @ $50/hr x 0.5)[2]		208
Total patients' indirect costs	**1,560**	**624**

[1] Researchers' assumptions.
[2] Assuming half of the patients receiving scans require a caregiver in attendance.

For an equal throughput of 2,080 scans per year (1 scan/hour, 8 hours/shift, 5 days/week, 52 weeks), it costs $135 more in fixed costs and $48 in operating costs to scan a patient with a mobile unit than a fixed unit. These increased costs would decrease as throughput increases. However, a mobile MRI will be less costly to patients who could save (in our example) $118 per scan in travels costs thus reducing the additional cost of a mobile unit over a fixed site. Moreover, when patients' indirect costs (lost time, etc.) are accounted for they could make the mobile option even less costly. In our example, indirect costs would be less than those associated with a fixed MRI by $450 per scan, thus making the mobile unit option less costly. A summary of the increased costs per scan of a mobile MRI unit versus a fixed MRI site is provided in Table 6.

Table 6 - Increased Costs per Scan of a Mobile MRI v/s a Fixed MRI)

Total fixed costs	+134.60
Total operating costs	+48.10
Total patient direct costs	-118.30
Total patient indirect costs	-450.00
Total	**-385.60**

Intangibles

In addition to direct and indirect costs, a number of intangible factors should also be considered. The following table illustrates a few of them.

Table 7 - Intangibles

Fixed Site	Mobile Unit
Inconveniences experienced by the patient.	More claustrophobic to patients
Inconveniences experienced by family members, significant others accompanying patient	Emergency services not always readily available

DISCUSSION

Technologically speaking, there appear to be few reasons why mobile technology is not feasible. However, the Ontario Radiologists' Association (OAR) contends that the disadvantages of mobile technology largely outweigh the benefits (H. Gillis, personal communication). This sentiment is also in agreement with the Royal College of Radiologists in the U.K. who state that "fixed sites ensure better access and reduce overall costs" (The Royal College of Radiologists, 1992, p. 9).

Some of the potential disadvantages of mobile MRI, which may also be applied to mobile CT, as summarized by the OAR (1994) include:

- image quality may be compromised due to the mobile environment, the vibration experienced by the unit, and the fact that it may take those working with a mobile unit longer to achieve a level of proficiency as experienced by the staff working at a fixed site
- the mobile unit is not always at a given site therefore not always available for dealing with emergencies
- there are transportation costs such as mileage, driver's salary, insurance, etc. that are associated only with mobile technology
- there is an increased amount of downtime required by a mobile unit due to increased maintenance requirements and travel time
- compared to a fixed site, the interior space of a mobile scanner is limited
- winter conditions may cause delays or loss of the unit due to accidents, and longer travel times.

Advantages of mobile technology include:

- the ability to share costs and services among several sites
- patients do not have to travel to benefit from CT and MR services
- decreased preinstallation and site costs (specifically for mobile MRI)
- the provision of an opportunity to test a technology prior to buying a system
- the opportunity to alter the number of days at each site related to volume requirements (OAR, 1994).

With the increased accessability afforded by mobile technology, there might possibly be an increase in utilization. The utilization of CT and MRI is very different. CT utilization is limited by not only cost/benefit factors but risk/benefit factors which arise from exposure to ionizing radiation. Kaufman et al. (1989) prefer to compare MRI utilization to that of ultrasound. The utilization of ultrasound has increased very rapidly because it is not limited by risk/benefit factors such as CT. This also applies to MRI, a noninvasive modality limited primarily by the resources (equipment, human, etc.) which are required for installation and operation. In the United States the utilization of MRI has increased rapidly (although not as rapidly as CT). Although in Canada capital is not as readily available and reimbursement of such procedures is more controlled, a similar trend may be expected.

CONCLUSIONS

The technical specifications of fixed and mobile CT and MRI scanners are very similar if not the same. Given proper quality control programs and a proficient crew, image quality does not appear to be affected when these technologies are provided in a mobile environment. When CT and MRI diagnostic services are provided in a mobile setting, safety concerns are similar to those found at fixed sites, however, there is an increased incidence of claustrophobia associated with mobile units.

The decision of whether or not to purchase mobile technology should not only be based on costs, but the opportunity to provide MRI and CT services to relatively close geographic regions that alone could not fully utilize the technology. Future population and health trends also need to be factored into the decision. Due to the declining cost of CT scanners, the total fixed costs of a mobile unit may be more than those for a fixed site. The total fixed costs of a mobile MRI are in some cases still lower than those of a fixed site. Finally, although there are increased operating costs with mobile CT and MRI technology, these costs may be offset by increased throughput, flexibility, and other costs (particularly those indirect costs experienced by patients in areas where the technology is not readily available).

REFERENCES

---. Technology on wheels: Evaluating the options. **Health Technology** 1987; (6):231-238.

Appleby C. MRI's second chance. **Hospitals & Health Networks** 1995; 69(8):40-42.

Canadian Coordinating Office for Health Technology Assessment. **Selected health technologies in Canada** (Technology brief; Issue 5.3). Ottawa: Canadian Coordinating Office for Health Technology Assessment; 1994.

ECRI. **Health devices sourcebook, 1994** . Plymouth Meeting, PA: ECRI, 1994.

Erickson KA, Mackenzie KR, Marsha AJ. 1993. Advanced but expensive technology: balancing affordability with access in rural areas. **Canadian Family Physician** 1993;39(Jan):28,30,32,34.

GE Medical Systems. 1991-1993. **Signa Advantage: 1.5T, 1.0T, & 0.5T site planning** . [Technical publications: Direction 15402, revision 3]. [Toronto, ON]: General Electric Company.

Grossman ZD, Katz DS, Santelli ED, Math KR, Wasenko JJ. **Cost-effective diagnostic imaging: the clinician's guide** (3rd ed.). St. Louis, MO: Mosby-Year Book, Inc.; 1994.

Herman JG. Interior and exterior design of mobile imaging units. **Applied Radiology** 1986;15(3):93-98.

Iezzoni LI, Grad O, Moskowitz MA. Magnetic resonance imaging: overview of the technology and medical applications. **International Journal of Technology Assessment in Health Care** 1985;1(3):481-498.

Kaufman L, Arakawa M, Hale J, Rothschild P, Carlson J, Hake K, Kramer D, Lu W, Van Heteren J. Accessible magnetic resonance imaging. **Magnetic Resonance Quarterly** 1989;5(4):283-297.

O'Donovan PB. Computed tomography. In**:** Golish JA, (editor.), **Diagnostic procedure handbook** . Baltimore, MD: Williams & Wilkins; 1992. p.273-287.

Ontario Association of Radiologists. **Magnetic resonance imaging: position paper** . Toronto, ON: Ontario Association of Radiologists; 1994.

Padikal TN. A quality-assurance program for mobile CT scanners. **Applied Radiology** 1987;16(2):18-20, 25,61.

Rinck PA. Safety aspects: [Magnetic resonance]. **Hospimedica** 1991;(Aug/Sept):16-17.

Ross JS. Magnetic resonance imaging. In: Golish JA, (editor). **Diagnostic procedure handbook** . Baltimore, MD: Williams & Wilkins; 1992. p. 333-356.

Royal College of Radiologists. **Report of the working party on provision of magnetic resonance imaging services in the U.K** . London: Royal College of Radiologists; 1992.

Siemens Medical Systems. **Magnetrom Impact 1.0 tesla mobile MRI transportable "at-field"** . Iselin, NJ: MR Division, Siemens Medical Systems, Inc.; 1994.

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